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Performance of Successive Generations of Two Sugar Beet Varieties

H. E. Brewbaker and H. L. Bush[1]

During the early development of the sugar beet industry it was a generally accepted principle that continued selection was essential if quality and yielding ability were to be maintained in a variety. It was possible to do this using the steckling method of seed production from elite stock. However, with the advent of the overwintering method for seed production some two decades ago in the United States, the rate of seed increase from elite stock was materially less than for the steckling method, which made successive increases of each lot an acceptable practice if one were certain that no essential change would occur in later generations. Since the basic principle of loss in performance resulting from successive mass increases appeared open to question, some such increases, followed by performance tests, were made in the Great Western seed program to check out this principle.

Earlier tests as reported (1)[2] and (2) were promising and a general program of successive mass increases for commercial seed production adopted. During this time, performance tests have been conducted to assure safety in maintaining the general varietal characteristics, at least to the extent that if any change is detected, further increase would not be made.

In this paper the results for several generations of two important Great Western varieties of recent origin are presented. These varieties (304 and 359) have had a somewhat similar origin. Both resulted from a broad program of searching for types resistant to the leaf-spot disease, improving the various sources by family and progeny test methods, and finally bringing together the improved families from several original sources into respective polycrosses. Following these first polycrosses, there were two generations of family testing accompanied by selection within and between families.

In the Great Western system of numbering seed lots, seed from the first mass grouping of families is known as the "B" generation. One generation by mass increase of "B" seed results in the "C" or elite generation. Further successive mass increases become "commercial" seed and carry the prefix "GW" along with appropriate suffixes to designate year and location.

The comparative tests, for which data are included in the following tables, employed 12 replicates of each variety in either a Randomized Complete Block or Triple Rectangular Lattice design for each test. Plots as harvested were 6-rows wide and 18-feet long, all beets surrounding skips of 3 or more feet in length being discarded. Yields were then calculated on the basis of full stands for all beets harvested from 6 rows. Sugars and purities were obtained from all beets harvested from 2 rows of each plot.

Tables 1 and 2 include summaries of tests of the 304 variety for the two years, 1952 and 1953, at two locations and the 359 variety at the same locations for the four years, 1952 through 1955.

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[1] Director and Statistician-Agronomist, respectively, Agricultural Experiment Station, The Great Western Sugar Company, Longmont, Colorado.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Summaries of Tests of the 304 Variety for the Two Years 1952 and 1953 at Longmont and Fort Morgan, Colorado.

Variety No.[1]		Tons Beets Per Acre			Percent Sugar Content		
Increase	Origin	1953	1952	Mean	1953	1952	Mean
C304	Gr. 459	24.20	20.77	22.49	16.67	15.52	16.10
GW304-49A	C304	23.37	20.25	21.81	16.77	15.08	15.93
GW304-49R	C304	23.49	19.95	21.72	16.68	15.35	16.02
GW304-49L1	C304	23.99	20.88	22.44	16.89	15.76	16.33
GW304-50L	C304	23.56	19.99	21.78	16.89	15.28	16.09
GW304-50A	GW304-49R	23.20	20.44	21.82	16.82	15.34	16.08
GW304-50R	GW304-49R	22.80	19.62	21.21	16.81	15.57	16.19
GW304-51A	GW304-50R	23.33	19.34	21.34	16.83	15.37	16.10
LSD 5% pt.		.60	.98	.58	.31[2]	.43	.27[2]

Variety No.[1]		Percent Bolters			Percent[3] Thin Juice App. Purity	Percent[3] Sodium
Increase	Origin	1953	1952	Mean	1953	1953
C304	Gr. 459	.56	.04	.30	93.99	.034
GW304-49A	C304	.49	.32	.41	93.28	.041
GW304-49R	C304	1.46	.18	.82	94.05	.042
GW304-49L1	C304	.63	.28	.46	93.81	.036
GW304-50L	C304	.66	.11	.39	93.64	.040
GW304-50A	GW304-49R	1.18	.25	.72	94.09	.038
GW304-50R	GW304-49R	1.28	.18	.73	93.65	.043
GW304-51A	GW304-50R	.66	.11	.39	93.91	.039
LSD 5% pt.		—	—	—	.82[2]	.005

[1] Suffix includes year and location (A, R, L for Arizona, Oregon and Longmont, Colorado.

[2] No significant differences indicated by the "F" test.

[3] Fort Morgan only.

For variety 304 (Table 1) there is some indication of a reduction in yield for the 49A, 49R and 50L increases but the 49L1 increase was equal with C304, the parent of all of these increases. The average difference between the 50A and 50R increases for the two locations is slightly in excess of the difference of .58 tons required for significance at the 5 percent level although both were increases from the same lot. A reduction in yield of 1.15 tons per acre for 50R, the third increase, as compared with the original C304 is highly significant. In consideration of these variations in performance, the picture with respect to any loss in tonnage is certainly not clear. With the 49L1 exception, however, all increases are significantly below the original C304 in yield as an average for two locations. For neither sugar content nor purity is there any indication of any change with successive generations. For sodium, 5 of the increase lots were slightly but significantly

Table 2.—Summaries of Tests of the 359 Variety for the Four Years 1952 through 1955 at Longmont and Fort Morgan, Colorado.

Variety No.[1]		Tons Beets per Acre				Percent Sugar Content			
Increase	Origin	1955	1954	1953	1952	1955	1954	1953	1952
B359	Gr. 4610	—	—	24.22	19.37	—	—	17.13	15.80
C359-49L	B359	22.43	21.02	24.22	20.33	16.87	15.83	17.34	15.85
C359-50R	B359	22.30	20.07	23.90	19.70	16.65	15.76	17.34	15.77
GW359-50L	C359-49L	22.51	20.91	23.89	20.03	16.74	15.94	17.17	16.00
GW359-51A	C359-50R	22.28	20.97	24.10	19.74	16.51	15.63	17.07	15.57
GW359-51R	C359-50R	21.91	20.39	24.10	19.92	16.78	15.99	17.38	15.93
GW359-53R	C359-50R	22.43	20.65	—	—	16.39	15.87	—	—
GW359-52A	GW359-51R	21.92	19.59	23.98	—	16.63	15.87	17.14	—
GW359-52R	GW359-51R	22.09	20.10	23.55	—	16.56	15.80	17.23	—
GW359-54A1	GW359-51R	22.10	—	—	—	16.42	—	—	—
GW359-54A2	GW359-52R	21.49	—	—	—	16.37	—	—	—
LSD 5% pt.		0.91	0.93	0.78	0.97	0.24	0.34	0.32	0.33

Variety No.[1]		Percent Bolters				Percent Thin Juice[2] App. Purity	Percent Sodium
Increase	Origin	1955	1954	1953	1952	1953	1953
B359	Gr. 4610	—	—	0.49	0.00	93.71	.033
C359-49L	B359	0.39	0.04	0.49	0.00	93.42	.030
C359-50R	B359	0.81	0.27	1.57	0.00	94.09	.033
GW359-50L	C359-49L	0.93	0.04	1.11	0.14	93.47	.037
GW359-51A	C359-50R	1.08	0.16	0.56	0.14	94.09	.037
GW359-51R	C359-50R	1.12	0.24	0.90	0.11	93.36	.036
GW359-53R	C359-50R	1.08	0.16	—	—	—	—
GW359-52A	GW359-51R	0.74	0.08	0.25	—	94.26	.038
GW359-52R	GW359-51R	1.66	0.39	2.50	—	93.88	.034
GW359-54A1	GW359-51R	1.28	—	—	—	—	—
GW359-54A2	GW359-52R	1.43	—	—	—	—	—
LSD 5% pt.		—	—	—	—	0.76	.005

[1] Suffix includes year and location (A, R, L for Arizona, Oregon and Longmont, Colorado.)

[2] Fort Morgan, only.

above the original C304. For bolters, one might anticipate some differential, and for 1953 the differences between varieties are large enough to indicate some probable real increase for the 49R, 50A and 50R lots.

For Variety 359 (Table 2), there was no indication of change for any character except bolting in any successive increase prior to the 54A2 lot tested in 1955. This lot is essentially equal in yield to its immediate parent, 52R, and to its grandparent 51R, but as compared with the original C359-50R,

the apparent loss in yield is about equal to the LSD at the 5 percent level. There appears to have been some increase in bolters for the later generations, more or less, regardless of location of the seed increase.

As evidence that it is impossible to predict the performance of successive generations, it may be pointed out that 304 levelled out after the "C" generation, while there did not appear to be any apparent loss in performance for 359 through three increases after the "B" generation, with a possible slight loss in yield in the fourth.

Summary and Conclusions

Successive mass increases have been made without selection during the past 20 years or more as a general practice with Great Western varieties. As a constant check against any possibility of loss in yield or sugar, or changes in other important characters, generation studies have been continued year after year.

From previous reports and from the data included in this paper, certain instances of possible genetic changes usually losses in yielding ability, have been encountered. Generally they have been rather small and therefore difficult to determine with certainty.

It seems safe to conclude that quality, as measured by sugar content and purity, has remained constant through several generations of mass increase. Bolters have increased not greatly but rather definitely in some cases. A program of seed production by continued mass increase without selection appears practical and with little danger of serious loss in any important character for varieties having a heterogenous and broad base composition, such as were used in these tests. But it is important that each increase be checked for performance in comparison with the parental strains.

References

(1) BREWBAKER, H. E. 1940. Performance of direct increases of pedigreed and commercial lots of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. II (1); 147-148.

(2) BREWBAKER, H. E. and BUSH, H. L. 1942. Generations studies of sugar beet varieties. Proc. Amer. Soc. Sugar Beet Tech. III: 342-348.

Compaction Caused by Tractor Wheels in the Cultivation of Sugar Beets

O. W. Monson[1]

The cultivation of sugar beets, five or six times during the season, has a cumulative compacting effect on the soil, the results of which have not yet been fully or definitely determined. That considerable compaction occurs is readily admitted since on all of the seeding and cultivating operations, the equipment used is so designed that the tractor wheels travel in the same row or path each time. For four-row equipment this means that every other row becomes a path for a tractor wheel. The intervening rows, on the other hand, receive the full benefit of the cultivation because no compaction occurs.

The compacting force will, of course, depend on the total weight of the tractor and the weight distribution on the wheels of the tractor. For example, a Model A International Tractor[2], a size ordinarily used for cultivating sugar beets, weighs about 2,850 pounds with the driver. The weight distribution is as follows:

Front wheel 950 pounds or 475 each wheel
Rear wheels 1,900 pounds or 905 each wheel

With the beet cultivator mounted on the tractor, the total weight, with driver, is increased to 3,470 pounds; 1,160 on the front and 2,310 on the rear.

This tractor is equipped with 5-inch tires on the front wheels and 9-inch on the rear. The normal or prescribed inflation for these tires is 24 pounds of pressure in the front and 12 pounds in the rear. Such a tractor weighing 2,850 pounds with driver at Huntley Field Station, Montana, was used in connection with a study to measure the compaction which occurs when cultivating sugar beets.

The bearing surface of the tires on the ground was measured with the tractor standing still. The method used was to jack the wheel off the floor, paint the lower section of the tire with black paint, then lower the wheel onto a large sheet of paper. This left a clear impression of the bearing surface of the tire. Only the lugs left an impression on the paper. However, on loose soil the grooves between the lugs would also carry some of the load.

The area, in square inches, of the impression made by each tire was carefully measured with a planimeter. From these measurements, and the weight carried by each wheel, the pounds per square inch bearing pressure of the tractor wheel on the ground was calculated. The procedure described above was repeated for both front and rear tires while inflated four pounds above normal and four pounds below normal. The bearing surface and bearing pressure and pounds per square inch between wheel and ground are given in Table 1.

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[1]Irrigation Engineer, Montana Agricultural Experiment Station, Bozeman, Montana.
[2]A Model "A" tractor equipped as above was weighed at Huntley Field Station.

Table 1.—Compacting Force of Tractor Wheels with Tires Inflated Four Pounds Above Normal, Normal, and Four Pounds Below Normal.

Front Wheels	TIRE INFLATION		
	4 Pounds Above Normal 28 p.s.i.	Normal Pressure 24 p.s.i	4 Pounds Below Normal 20 p.s.i
Weight carried on each wheel	475 lbs.	475 lbs.	475 lbs.
Area of bearing surface of lugs	10.16 sq. in.	10.09 sq. in.	12.07 sq. in
Average weight per square inch bearing surface	46.8 lbs.	47.0 lbs.	39.4 lbs.

Rear Wheels	TIRE INFLATION		
	4 Pounds Above Normal	Normal Pressure	4 Pounds Below Normal
Weight carried on each wheel	950 lbs.	950 lbs.	950 lbs.
Area of bearing surface of lugs square inches	10.44 sq. in.	12.23 sq. in.	15.15 sq. in.
Average weight per square inch	91.0 lbs.	77.5 lbs.	62.6 lbs.

Note that the pounds per square inch bearing pressure of the front wheels when under inflated was nearly 20 percent less than with normal inflation. The pounds per square inch bearing pressure when inflated above normal was practically the same as normal. For the rear wheels the pounds per square inch bearing pressure was nearly 19 percent less when under inflated and 12 percent more when over inflated than with normal pressure. It is believed that the vibration of the tractor also affects the amount of compaction.

Compared to the above, the pressure from the hoof of an average work horse, weight 1,600 pounds, is about 21 pounds per square inch, and of a 160 pound man, 5.7 pounds per square inch. It should, of course, be remembered that the area compacted by a horse's hoof is comparatively small and that there is also little possibility that the horse would step in the same place each time during succeeding cultivations, whereas, the compaction from a tractor wheel is a continuous strip along the entire row. Thus, the cumulative compaction from horse's hoofs would not be so pronounced as from the tractor wheel.

Some idea of the amount of compaction which takes place in the beet row where the tractor wheel travels may be obtained by measuring the force required to drive a stake or bar into the soil. Such a test was made at the Huntley Field Station during the summer of 1955. A small pile driver was made which was used to drive a round bar into the ground by striking it with a hammer dropped from a given distance.

In the test described, a 10-pound weight was used for a hammer. It was dropped a distance of two feet for each blow. The bar driven into the ground was 1⅛ inches in diameter. Twenty-five blows were used for each test. The tests were made before and after irrigation and in each case were made in the row traveled by the tractor wheel and in the adjacent middle row.

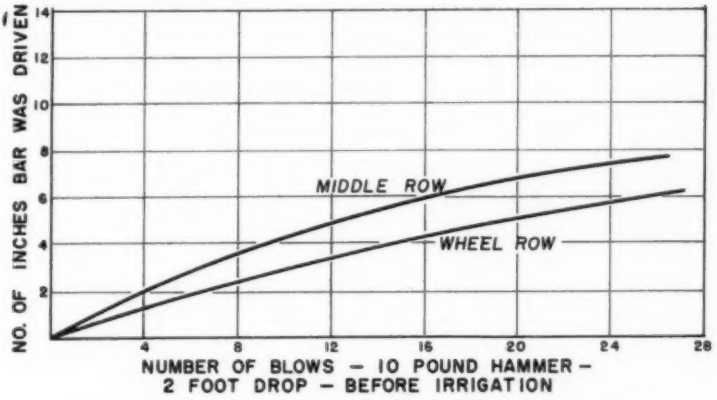

Figure 1.—Compaction tests, Field "K," Huntley Field Station.

The results of these tests can best be shown graphically. Figure 1, which is the average of five tests, shows a comparison between the resistance of the soil in the wheel row compared to the soil resistance in the middle row before irrigation. The data taken before irrigation show that the bar was driven 7.6 inches in the middle row and 5.9 inches in the wheel row which was 1.7 inches or 28 percent farther with 25 blows in the middle row than it was in the row compacted by the tractor wheel. After irrigation the test showed a difference of 2.3 inches or 20 percent in favor of the middle row (See Figure 2).

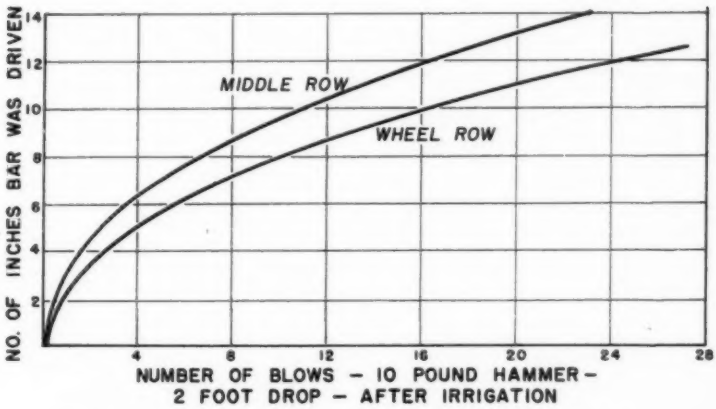

Figure 2.—Compaction tests, Field "O," Huntley Field Station.

Before irrigation, the effect of compaction appeared at a depth of one inch in the wheel row when the distance driven became less than one-fourth inch for each blow. In the middle row the bar was driven 5.4 inches before the resistance was great enough to reduce the distance driven per blow to less than one-fourth inch.

One day after irrigation a similar test was made. The results are shown in Figure 2. In this test the bar was driven 14.5 inches by 25 blows in the middle row compared to 12.1 inches in the wheel row. The bar was driven over three inches by the first blow of the hammer in the middle row as compared with 2.2 inches in the wheel row or nearly an inch farther. After 20 blows, the distance driven by one blow of the hammer dropped to less than one-fourth inch per blow in both cases, but the distance driven by 20 blows was nearly 13.2 inches in the middle row as compared to 10.9 inches in the wheel row.

These tests clearly show that tractor wheels cause considerable compaction. They also give a measure of the amount of compaction in the soil at the end of the season.

Irrigators recognize this condition and make allowance for the difference in rate of absorption of water. The general practice is to turn a smaller stream into the wheel rows because of the low intake rate, and a larger amount into the middle rows since the intake rate is greater. Where the plastic tubes are used, 2 one-inch tubes are set in the middle row and one in the wheel row. When the same size stream is turned into all rows, the wheel rows usually reach across the field in about one-half the time required for the others.

Infiltration readings were taken in both wheel rows and middle rows by the ring method. Six rings were used for this test; three in the wheel rows and three in adjacent middle rows. The results are shown in Figure 3.

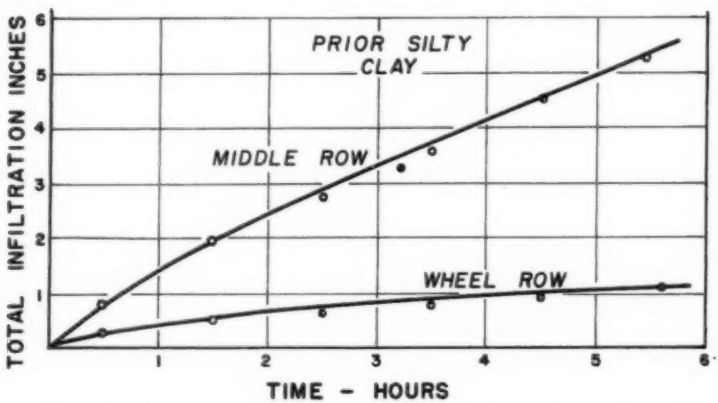

Figure 3.—Effect of compaction by tractor wheels on infiltration, Huntley Field Station.

These data show that a total of 5 5/16 inches of water were absorbed in the middle row in 5⅓ hours, almost an inch per hour. During the same time, 5½ hours, only 1⅛ inch was absorbed in the wheel row. This test was made at the end of the irrigation season after six cultivations. The tractor wheel had, therefore traveled seven times along the same path—once for seeding, six times during cultivating operations.

The last irrigation of the season was applied during the second week in September. The difference in time for the water to reach the end of the row between the middle furrows and those compacted by the tractor wheels was not as obvious because of the large shrinkage cracks in the soil. Many of these extended all the way across the row so that the water from adjacent rows intermingled to such an extent that all rows reached the end at the same time.

There was, however, a difference between rows in the amount of water stored in the soil. Soil samples taken before and after irrigation showed that with the moisture content approximately the same in all rows before irrigation, comparatively little absorption of water took place in the wheel row while the middle row absorbed the full field capacity. The soil where the tests were taken is a heavy silty clay.

It is not known to what extent compaction interferes with the root development but it is thought that compaction of the soil may affect the beet in two ways: (a) Through reduced aeration, and (b) through adverse change in structure. There is also the possibility that the soil fertility may be affected indirectly by the reduced aeration. Two dozen beets were carefully lifted so as not to damage the roots. The soil was then washed away by means of a fine spray of water. Before lifting, each beet was marked on the side next to the wheel row with a colored pencil.

After the soil had been washed away from the roots, the beets were carefully studied and photographed to determine if any significant differences in the root development existed. As far as could be observed, there were no differences in the root development on the two opposite sides of he beet, either in the total number of rootlets or their length. The fine oots of the beet occur in two grooves or bands. The band of roots sometimes urves half way around the beet. In some cases these bands of roots are on the sides of the beet next to the furrows. In other cases they are on opposite sides longitudinally in the rows. Their position appears to result from the accidental way the seed comes to rest when dropped from the drill.

The conclusions reached from this short study are as follows:

1. Considerable compaction occurs in the rows traveled by the tractor. This compaction is apparent from the driven bar test, both before and after irrigation.

2. The compaction causes a marked reduction in the rate of infiltration of irrigation water and also in the total amount of water stored in the soil from one irrigation. Whether or not this affects the yield of the sugar beets adversely is not known.

It is believed that the amount of compaction can be reduced by under inflation of the tractor tires. The amount of infiltration of water could, no doubt, be increased by widening the wheel row so a wide shallow furrow could be made. This would increase the area covered with water and also the amount of water entering the soil.

If wider equipment were designed, such as six or eight rows, the relative number of wheel rows in proportion to the total would be greatly reduced. Further studies are needed to determine to what extent compaction interferes with the growth and yield of sugar beets. Then measures to overcome the campacting effect of the tractor wheels can be devised as far as the expected benefits will justify.

Paper Chromatography of Sugar Beet Saponin Compounds

H. M. Bauserman and P. C. Hanzas[1]

Sugar beet saponin has been described as a glucuronic acid glycoside of a triterpene, oleanolic acid (2)[2]. Many workers have studied this and related compounds (1) (2) (3). The authors felt it advisable to study oleanolic acid, its glycoside, and their salts using paper chromatography. Knowledge thus gained should be useful in further studies of beets, beet products, and other plant materials containing similar substances. An attempt was made to utilize the chromatographic characterizations thus obtained to determine the nature of saponins as they occur in beets. Certain difficulties were encountered, perhaps due to the presence of colloids or other substances capable of forming more or less firmly bound additional products.

In the laboratory many experimental beets are analyzed for various constituents by paper chromatography. An isopropanol solvent has been developed by the laboratory which, with descending paper chromatography, is suitable for the separation of sugars, such as raffinose, galactinol, inositol, and for separation of at least nine of the amino acids commonly found in sugar beets. The above juice compounds align themselves in identical positions on paper chromatograms with the respective pure chemicals thereof. Such is not the case with purified saponin and saponin of beet juice. The pure saponin moves with the solvent front while the beet juice saponin has moved only half the distance. Smolenski (3) in 1935 foung magnesium saponin present in diffusion juice. Thus saponin, possibly present in the form of salts, might account for its unusual chromatographic properties.

Methods

One and two dimensional chromatographs were matle on Whatman No. 4 paper using the following solvents: a. benzene; b. isopropanol; c. methanol-water; and d. water. The spots to be chromatographed contained either a few micrograms of the relatively pure salts of 2.5 milligrams of total dry substance when sucrose was present, and 100 micrograms of egg albumin when used.

Solvents

Isopropanol Solvent consists of:
- 70 parts isopropyl alcohol
- 10 parts N-Butanol
- 25 parts benzene
- 25 parts water

Methanol Solvent consists of:
- 95 parts 95% methanol
- 5 parts distilled water

Water

Benzene

The solvents traveled down the paper chromatographs.

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[1] Head Research Chemist and Research Chemist respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

[2] Numbers in parentheses refer to literature cited.

Color Reagents

Antimony Pentachloride:
5 ml. Antimony pentachloride
95 ml. chloroform
0.5 gm. antimony trichloride

Alpha Naphthol:
1 gm. alpha Naphthol
100 ml. solox
15 ml. phosphoric acid

8-Hydroxy quinoline (oxine)
0.5 gm. 8-hydroxy quinoline
100 ml. N-Butanol

The antimony pentachloride reagent reacts with saponin to form a pink color. The dried chromatograms were dipped in antimony pentachloride and placed in an oven for a few seconds at 90° C.

Chromatographs, after being dipped in antimony pentachloride, were then treated with alpha Naphthol reagent heated to 90° C. to bring out the purple color of sucrose when present.

The chromatographs were dipped in oxine reagent, allowed to dry at room temperature, exposed to ammonia fumes, then examined under ultraviolet light. Magnesium, calcium and barium each produce a bright fluorescence.

Table 1.—Rf Values of Purified Saponin Compounds.

Compounds	Rf Values in Indicated Solvents			
	Isopropanol	Water	Methanol-Water	Benene
Mg saponin	0.0	0.0	0.0	0.0
	0.3 - 0.6*	0.6 - 0.8*	0.8 - 1.0*	
Ca saponin	0.0	0.0	0.0	0.0
Ba saponin	0.0	0.0	0.0	0.0
Na saponin	0.0	0.0	0.0	0.0
	0.3 - 0.6*	0.7 - 0.9*	0.3 - 0.4*	0.0
			0.9 - 1.0	
K saponin	0.0	0.0	0.0	0.0
		0.6 - 0.7*	0.2 - 0.3	
			0.7 - 1.0	
NH_4 saponin	0.3 - 0.8*	0.0	0.0	0.0
	1.0		0.6 - 1.0	
beet juice saponin	0.4 - 0.6*	0.0	0.0	0.0
		0.6 -0.8*	0.0 - 0.3	
			0.4 - 0.7*	
saponin	1.0	0.0	1.0	0.0
oleanolic acid	1.0	0.0	0.0	1.0

*Strong pink

The saponin was purified according to the method of Walker and Owens (4). The salts of saponin were prepared by mixing purified saponin and the respective oxide or hydroxide of the metal in water, filtering and using the filtrates for the various chromatographic tests.

Results and Discussion

The term Rf as used here is the value of the ratio of the distance traveled by the compound to the distance traveled by the solvent. Instead of giving the average Rf for a spot, the upper and lower limits are listed in the tables.

Table 1 reports the results obtained with purified saponin salts only.

In benzene, none of the compounds showed any mobility except oleanolic acid. Calcium and barium saponin had 0.0 Rf in all the solvents. The magnesium saponin preparation produced a pink spot at 0.0 Rf in all four solvents; stronger pink spots occurred at locations which matched the beet juice saponin when using isopropanol or water, but not with methanol. In each case magnesium, barium, or calcium was found associated with the pink spots produced by Mg saponin, Ba saponin, or Ca saponin.

Table 2.—Rf Values of Saponin Compounds When Beet Juice Was Present.

Compounds	Rf Values in Indicated Solvents		
	Isopropanol	Water	Methanol-Water
Mg saponin	0.0	0.0	0.0
	0.4 - 0.6*	0.6 - 0.8*	0.0 - 0.3
			0.5 - 0.9*
Ca saponin	0.0*	0.0*	0.0*
	0.4 - 0.6	0.6 - 0.8	02. - 0.4
			0.6 - 0.8
Ba saponin	0.0*	0.0	0.0*
	0.4 - 0.6		0.0 - 0.2
			0.5 - 0.8
Na saponin	0.0	0.0	0.0
	0.2 - 0.4*	0.6 - 0.9*	0.1 - 0.4
			0.5 - 0.8*
K saponin	0.0	0.0	0.0
		0.5 - 0.6*	0.0 - 0.2
		0.6 - 0.8*	0.5 - 0.9*
NH_4 saponin	0.3 - 0.8*	0.0	0.0
	1.0		streak
beet juice	0.4 - 0.6	0.0	0.0
		0.6 - 0.8*	0.0 - 0.3
			0.4 - 0.7*
saponin	0.4 - 0.6*	0.0*	0.0
	1.0*	0.6 - 0.8*	0.0 - 0.3
			0.4 - 0.7*
			1.0*

* Strong pink

An extensive series of tests using all solvents indicated that incorporation of sucrose in the salt solutions did not alter the Rfs of the various salts.

Study of Table 2 reveals that the Rfs of the pink spots resulting from the mixtures of sodium saponin and beet juice or magnesium saponin and beet juice were similar to those of beet juice alone in all three solvents. The calcium saponin and barium saponin fixed some of the mobile beet juice saponin at 0.0 Rf, probably due to an excess of calcium and barium ions present.

Table 3.—Rf Values of Saponin Compounds When Sucrose and Egg Albumin Were Present.

Compounds	Rf Values in Indicated Solvents		
	Isopropanol	Water	Methanol-Water
Na saponin	0.0	0.0	0.0
	0.5 - 0.6*	0.5 - 0.8*	0.3 - 0.5*
	1.0		
K saponin	0.0	0.0	0.0*
	0.5 - 0.6*	0.4 - 0.7*	0.0 - 0.2
	1.0		
NH_4 saponin	0.5 - 0.6*	0.0	0.0
	0.8 - 1.0	0.3 - 0.7*	0.2 - 0.5
Mg saponin	0.0	0.0	0.0
	0.4 - 0.6*	0.6 - 0.8*	0.4 - 0.6*
saponin	1.0	0.0	1.0

* Strong pink

Table 3 shows the effect of the presence of sucrose and albumin. They seemed to affect the Rf values of the saponin salts, in that sodium and magnesium saponin moved to positions similar to the major part of the saponin of beet juice, but the presence of sugar and albumin did not affect purified saponin. Using isopropanol solvent or water solvent, potassium and ammonium saponin acted similarly to beet juice saponin, but not with the methanol solvent.

Beet juice was chromatographed. The pink spots resulting from treatment with antimony pentachloride were cut out, ashed, and analyzed for sodium, potassium, calcium, and magnesium by flame spectrophotometer. Five ml. of 10 percent dry substance beet juice was spotted along a four-inch line of Eaton-Diekman No. 301 paper and irrigated in two directions. This was done in water then methanol; methanol then isopropanol; and in water then isopropanol. The colors were developed with antimony pentachloride and the pink spots cut out and ashed. Blanks were also run. Similar areas of the blank sheets were treated in the same manner. With the water then methanol irrigation, potassium was found present in the greatest amount, some sodium, very little calcium, and no magnesium. The same pattern persisted for methanol then isopropanol, however, with water then isopropanol, all were present.

Chromatographic characteristics of saponin of beet juice by two dimensional chromatography were determined in several solvent systems as follows:

a. Water then Isopropanol

In the first direction in water, two saponin spots were formed, one at the 0.0 Rf and the other (major portion) at 0.5 Rf. In the second direction with isopropanol, both spots had an Rf of 0.4.

b. Isopropanol then Water

In the first direction, only one spot appeared and that at an Rf of 0.5. In the second direction in water, two saponin spots were formed one at 0.0. Rf and the other at 0.7.

c. Water then Methanol

In water two spots were found at 0.0 Rf and at 0.6 Rf. In the other direction in methanol, three saponin spots were formed, one at 0.0. Rf, another moved out from the 0.0 Rf in the first direction to an Rf of 0.7, and the third at 0.7.

The sucrose was always nearby the major part of the beet juice saponin. In isopropanol, saponin located itself immediately below the sucrose, while in water or methanol solvents, the two usually occupied the same position.

Summary

1. The Rf values of the saponin salts were determined.

2. Magnesium and sodium saponin produced pink spots which appear to be similar in Rf to part of the beet juice saponin. Sucrose and albumin together seemed to affect the chromatographic values of the salts.

3. Potassium, sodium, calcium and magnesium were found in pink spots of beet juice saponin by flame spectrophotometer.

4. Beet juice saponin was separated into several areas by two dimensional chromatography.

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The Sugar Beet Root Maggot in North Dakota[1]

J. A. Callenbach, W. L. Gojmerac and D. B. Ogden[2]

The sugar beet root maggot, *Tetanops myopaeformis* (von Roder), has become a pest of beets in the Red River Valley of North Dakota. It is known to be present from the Canadian border south to Hillsboro in Traill County. However, economic damage appears to be limited to the lighter soil areas with the more severely damaged fields in southern Pembina and northern Walsh Counties.

Biology

Jones, et al. (1)[3] summarized the known history of the insect up to 1952, described the damage, and gave the essential features of its life history as it occurs in southern Idaho.

In the Red River Valley of North Dakota adult flies emerge in June and lay their eggs in the soil around the small beet plants. Maggots attack the roots of the beets and cause the most severe damage during July. Feeding appears to be completed in early August and the maggots move away from the beets. They gradually move downward in the soil and are found at depths of 6 to 12 inches at the end of the season. Hibernation occurs in the larval stage; pupation occurs in the spring.

Many details of the biology and ecology of the insect are as yet unavailable; for example, adult emergence is subject to considerable fluctuation. In 1954 the peak of adult activity was about June 28, in 1955 about June 14. In 1955 egg laying was at its maximum when most growers were conducting thinning operations. Little is known of the effects of these cultural measures on egg-laying behavior, egg hatch, and larval survival. It seems probable that variations in these practices may have significant effects on root-maggot populations.

It appears that the insect has a compulsory diapause. All efforts to obtain pupation and emergence of adults without subjecting the larvae to cold temperatures were unsuccessful. How much cold and how long the exposure must be is unknown. Preliminary tests indicate considerable tolerance of sub-freezing temperatures. Absolute minimums or length of exposure to various sub-freezing temperatures are again unknown.

Pigweed (*Amaranthus retroflexus*) and lambsquarters (*Chenopodium album*), both common weeds, were reported as hosts by Hawley (2). Infested pigweed plants were found in North Dakota in 1955. Possibly other related plants are also acceptable hosts.

The adult fly is sometimes extremely active and difficult to catch. At other times it may reverse this behavior and almost resemble a sweat bee; at such times it will not fly unless prodded and can often be caught with the hands. The latter behavior seems associated with egg-laying activities, the former is probably associated with migration to host-plant areas. How

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[3] Numbers in parentheses refer to literature cited.

far and the direction in which flight occurs has not been determined. General observations indicate the flight is random since large populations have been observed in grain and potato fields as well as sugar beet fields. Furthermore, flight may continue for distances of at least one-half mile; evidence of extremely heavy movements of one-fouth mile has been recorded.

Control

Control recommendations in western beet growing areas include regulation of soil moisture by irrigation, seed treatment, and fertilizer-insecticide mixtures applied as broadcast treatments. Since no irrigation is available, this measure is not applicable to beet culture in the Red River Valley. Seed treatment with lindane is used for wireworm culture but few data on its effectiveness for root-maggot control are available. Broadcast applications of fertilizer are not the usual procedure; instead, the fertilizer (only phosphate is used) is drilled directly into the row with the seed.

Hawley (2) reported that the fly has a pre-oviposition period of about ten days. It is theoretically possible then, to control the pest by killing the adults before egg laying begins. In 1954 preliminary experiments in North Dakota gave some evidence of reduced damage where sprays were applied to control the adults.

Upon the basis of this rather fragmentary information, the 1955 experimental control plots were developed. Control was attempted by means of seed treatments, insecticide-fertilizer mixtures applied with the seed, and by spraying to kill the adult flies.

Am 3N seed from the same seed lot was used in all seed treatment and fertilizer-insecticide mixture plots. Commercial fields were utilized for adult control plots; consequently, the seed source varied.

Seed Treatments

If successful, seed treatment would be a simple and inexpensive method of control. Seed could be treated prior to delivery insuring complete participation of growers making the cost very low.

Plots were placed on four farms in the area around Auburn, North Dakota. Randomized single-row 100-foot plots were replicated four times on each farm. The rows were marked with a standard-type beet drill and 0-46-0 fertilizer was applied at the rate of 100 pounds per acre in the rows at time of marking. The treated seed was then planted with Planet Junior hand seeders at the rate of 5 pounds per acre. The following materials were used: 75 percent aldrin, 75 percent dieldrin, 75 percent heptachlor, 75 percent lindane, 50 percent American Cyanamid 12008, 50 percent American Cyanamid 3911, and 25 percent Hercules AC 528. All materials were wettable powders and were applied at rates of .5 pound and .75 pound actual insecticide per 100 pounds of seed. DDT 50 percent wettable powder was applied at rates of .5 pound and 1 pound actual per 100 pounds of seed. Insecticides were applied to seed previously treated with Phygon and to untreated seed. Checks with Phygon treatment and no treatment were included in the tests.

Emergence of beets was recorded by counting three 100-inch portions of each row. Any phytotoxic effects of treatments would be evident from these counts. After thinning, the beets remaining in each 100-foot row were

counted. On August 1, all rows were again counted to determine the reduction in stand resulting from maggot attacks. At harvest, yields were taken from a 50-foot portion of each row.

No significant differences in original stand or in after-thinning stand were recorded. Likewise, yield data showed no increase of treated over untreated rows.

Adult Fly Control

Randomized plots 275 feet long and 204 feet wide (117 rows with 20-inch spacings) replicated two times on each of three farms in the Auburn area were sprayed at about the peak of fly activity. Sprays were applied at the rate of 15 gallons per acre using 400 pounds pressure. Nozzles were located approximately over the rows but the boom was adjusted so the entire surface area of the plots was covered with spray.

Aldrin, dieldrin, heptachlor, and Hercules AC 528 at .5 pound per acre, and endrin at .4 pound per acre were the insecticides used. Checks were left in all plot areas. In addition to the above, one-half gallon of beet molasses added as an attractant to aldrin and endrin sprays was applied to plots on two farms and one plot was sprayed with American Cyanamid 3911 at .5 pound per acre.

Effectiveness of the spray treatments was evaluated by counting the number of beets remaining in representative portions of the row after maggot damage was completed. For this purpose five sample areas near the center of each plot were selected. Each sample area was four rows wide and 50 feet long; thus counts were made from 1000 feet of row in each plot. While many dead flies were seen on the ground following spray applications, the stand counts showed no increase in sprayed over unsprayed plots; likewise, there was no decrease in the percent of stunted plants in the treated plots. Stunted plants are those which have recovered after maggot attack. No yield data were taken.

Insecticide-Fertilizer Mixtures

Conforming with the standard practice of fertilizer application in the area, an 0-46-0 fertilizer was used with applications calibrated at approximately 100 pounds per acre. Except for the dieldrin wettable powder, insecticides were obtained as 30-60 mesh granular formulations. Aldrin and heptachlor were 25 percent materials and dieldrin was a 10 percent formulation. In the plots where dieldrin was used in wettable powder form, a 50 percent wettable powder was used. Fertilizer and insecticide were mixed together in a cement mixer. Some differences in bulk resulted from the use of different percentage formulations and different types of materials, but the variations are not believed to be significant.

Randomized plots six rows wide and 100 feet long, replicated four times, were planted on four farms. Phygon-treated seed was used in all plots. Table 1 gives the materials used and rates of application. Stand counts were recorded by making three 100-inch counts per plot. After thinning, counts were made in three 95-foot rows in each plot and on August 1, the same rows were recounted. Yields were taken from two 50-foot portions of row in each plot. On three farms the plots were mechanically harvested and on the fourth farm they were harvested by hand.

Table 1.—Fertilizer - Insecticide Mixtures for Control of Sugar Beet Root Maggot. Summary of Data From Four Farms, Auburn, North Dakota, 1955.

Treatment	Total Initial Stand	Total Stand After Thinning	Total Stand August 1	Yield Per Acre (tons)
Aldrin 1 lb./A	1002	673	665	13.08
Aldrin 2 lbs./A	1043	659	653	13.53
Heptachlor 1 lb./A	1229	676	669	15.29
Heptachlor 2 lbs./A	1123	648	642	14.62
Dieldrin 1 lb./A	1094	677	671	13.21
Dieldrin 2 lbs./A	1028	665	654	14.93
Dieldrin w.p. 2 lbs./A	1206	701	686	14.53
Check	1496	689	633	11.83

Table 1 records initial stand, stand after thinning, stand on August 1, and yield in tons per acre for all treatments on all farms.

It should be noted that the initial stand in all treatments was less than the check. This was true for all treatments on all farms and indicates a phytotoxic effect from the treatments. By careful thinning these differences were to a great extent eliminated.

Data show increased yields from the use of all fertilizer-insecticide mixtures. Since they represent one year's data only, and because some error was observed in the mechanically harvested plots, the increases and differences between treatments may not be significant.

Figure 1 shows typical examples of untreated plots and plots treated with insecticide-fertilizer mixtures.

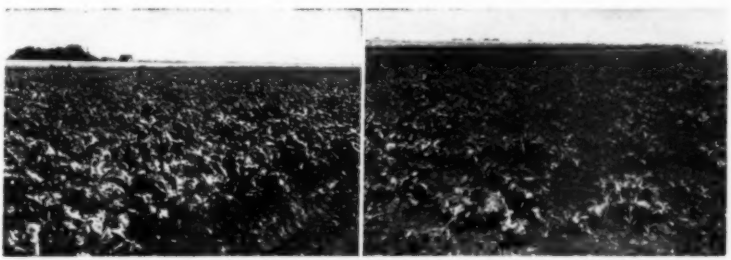

Figure 1.—Effects of fertilizer-insecticide treatments. Beets in left hand picture treated with fertilizer-insecticide mixtures. Beets in right hand picture untreated. Pictures taken in same field on same day.

Figure 2 shows differences in yield recorded from a 50-foot row sample of a treated plot as compared to a check plot.

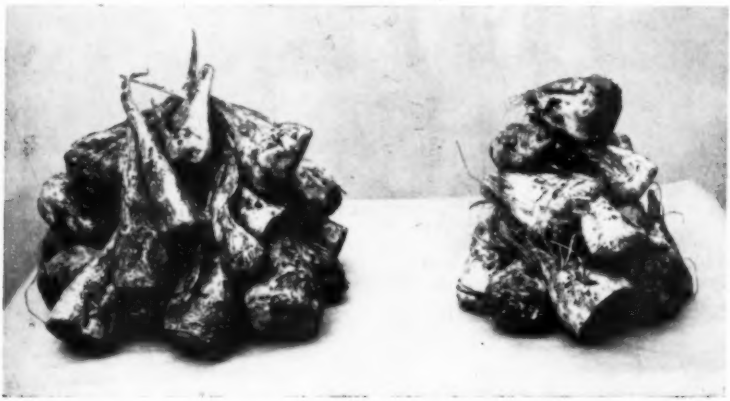

Figure 2.—Beet samples from rows treated with insecticide-fertilizer mixture, and fertilizer only. Treated row on left, check on right.

Note not only the difference in the number of beets, but their size and conformation. Beets from the treated plot have long tap roots; beets in the check are short and stubby, the tap roots having been severed by the maggots. Larger size of beets in the check is due to thinning of the stand by the maggot. Short, stubby beets are poorly anchored in the soil and may be pulled out when the beets are topped. This was observed to cause some loss due to failure of the digger to recover these displaced beets.

Sugar content of beets from treated and untreated plots was not significantly different although a slightly higher content was found in beets from treated plots.

Summary

The sugar beet root maggot is a major problem in sugar beet production on the lighter soils of the Red River Valley of North Dakota.

While the general pattern of the seasonal history of the maggot is known, many details of its biology and ecology are as yet unavailable.

Extensive control experiments demonstrated that seed treatments and control of adult flies were ineffective, but fertilizer-insecticide mixtures gave encouraging results. Since the data are from one year's investigations only, definite conclusions cannot be drawn. However, heptachlor, aldrin, and dieldrin at 1 pound per acre mixed with 0-46-0 fertilizer and drilled into the rows with the seed appear to offer promise.

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The Use of Dalapon for Grass Control in Sugar Beets

LAWRENCE SOUTHWICK, J. W. GIBSON, R. N. RAYNOR AND R. L. WARDEN[1]

Introduction

During 1954, 1955 and 1956, a considerable number of experiments were undertaken in most sugar-beet growing areas to determine the possibilities of using dalapon, sodium salt (Dowpon) to control grass weeds in beets. In this connection, it is of interest to note that annual planting of sugar beets in this country amounts to more than three-fourths million acres and represents commercial production in some 20 states; from Ohio and Michigan in the East to Texas and California in the South and West and in the intermountain and northwest areas. This wide area of production represents widely diverse conditions in regard to soils, air temperatures, broadleaved and grass weeds involved, beet varieties, and production techniques, including irrigation practices, irrigation versus no irrigation as well as mechanical versus hand thinning and harvesting.

Literature Review

As early as 1953 L. E. Warren (8)[2] conducted extensive trials in California with dalapon to control annual grasses—particularly water grass (*Echinochloa crusgalli*), in sugar beets. Conclusions resulting from the field and laboratory work were: dalapon, sodium salt controlled seedling grasses from the germination to early stooling stages when applied at temperatures ranging from 55° to 100° F. in spray volumes of 12.5 to 100 gallons per acre; 3 to 4 pounds (acid equivalent) of dalapon, sodium salt per acre controlled water grass when adequate wetting of the grass was obtained; more than 4 pounds as an over-all foliage treatment or more than one application tended to cause some yield reduction in weed-free beets; rates up to 7 pounds per acre did not affect sucrose content.

In Manitoba, Canada, Friesen (4) reported post-emergent treatment with Dowpon at 2 and 4 pounds dalapon equivalent gave complete control of green foxtail. Fair suppression of wild oats and mustard was obtained with the high rate. There was no injury to the sugar beets.

In Wyoming, studies by Alley and Bohmont (1) during the period 1953-1955 showed that the sodium salt of dalapon at 6 pounds acid equivalent per acre gave good grass control without reducing beet yield. Grasses controlled included tame oats, foxtail, and water grass. At 10 pounds, yields were adversely affected. Sucrose percentage was not affected by any dalapon rate. It was concluded that air temperature at the time of treatment may be an important factor in the use of dalapon for selective weed control in beets. At temperatures above 70° F., selectivity may be lessened. At 60° F., good grass control could be expected with no measurable adverse effect on the beets. Also, up to 50 percent of the broadleaves was controlled in some experiments.

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[1] Agricultural Chemical Development, The Dow Chemical Company. Located at Midland, Michigan; Oklahoma City, Oklahoma; San Francisco, California; and Minneapolis, Minnesota, respectively.

[2] Numbers in parentheses refer to literature cited.

Anderson and Helgeson (2) in North Dakota found that Dowpon at 5½ pounds applied anytime from the cotyledon stage to the 4 true-leaf stage in weed-free beets, caused no reduction in yield but at 8 pounds did cause a reduction. When applied at the 6 to 10 true-leaf stage two weeks later, the yield reduction at 5½ and 8 pounds was approximately the same and was small. There was no effect on the sugar content. Surprisingly, application of 8 pounds caused less yield reduction at the 6 to 10 leaf stage than at the 4 leaf stage. In pre-emergence applications, 8 pounds Dowpon caused no reduction in yield of weed-free beets. Continuing their studies under weed-free conditions, Anderson and Helgeson[3] substantiated their earlier results in that dalapon at 4 and 6 pounds per acre gave a reduction in yield, but not to sugar percentage, when applied to beets at the 6 to 8 or 10 to 14 true-leaf stage. The four-pound rate applied at the 6 true-leaf stage, or earlier, did not reduce yield or sugar percentage of beets.

In Nebraska, Keyser (5) found that Dowpon at 2 to 8 pounds gave 50 to 90 percent control of green foxtail when applied just prior to beet emergence and caused no permanent damage to the beets. In Ohio and Colorado, workers (6), (7) report good grass control with little or no injury to beets.

Blouch and Gaskill (3) found that for the control of oats in beets the best application was at the cotyledonary stage of the sugar beets when the oats were 3 to 4 inches tall. Dowpon was used at 4, 6, and 10 pounds dalapon equivalent per acre. The high rate gave the best and only permanent control. The sharp inhibition of growth of the beets (7 to 14 days after spraying) disappeared and all treatments appeared approximately the same in 30 days. With regard to yield, there was no adverse effect from applications at the cotyledonary stage of beet growth, whereas, there was some effect from application at the 2 and 4 leaf stages. Tame oats were used in these experiments, since its response to dalapon was found to be the same as the response of wild oats.

Tests and Results

Studies in California conducted by The Dow Chemical Company during 1955 evaluated the efficiency of directional sprays versus over-all sprays. In a replicated experiment of randomized block design, Dowpon at 4 and 6 pounds dalapon acid equivalent, was applied with drop nozzles to the base of sugar beets infested with water grass that had regrown after thinning. The beets and grass were 10 to 12 inches high. The field was irrigated soon after treatment. Since the rows only were treated, the net amount actually used per acre was one-half the over-all dosage. Flat fan nozzles were oriented about 45° to the vertical and the fan set about 45° to the row line to achieve coverage of only the lower two to three inches of beet petioles and about five inches away from the row. The beet leaves were not shielded nor lifted, but coverage of the main portions of the grass growth was obtained. The data presented in Table 1, indicate no effect on yield from the 4 pound dalapon equivalent rate when compared to the yield of the hoed check. There seemed to be some effect from the 6-pound application but the somewhat poorer grass control, which was not explained, may have had some effect on the yield. Note the low yield in the untreated check.

[3] Abstract to be published in Research Report, North Central Weed Control Conference.

Table 1.—Sugar Beet Yields and Grass Infestation at Harvest—California, 1955.

Treatment	Yield Tons Beets	Percent Grass Infestation at Harvest
Untreated	7.2	75
5.5 lb. Dowpon (4 lb. dalapon equiv.)	18.9	13
8.0 lb. Dowpon (6 lb. dalapon equiv.)	15.3	21
Hoed clean	18.8	4

Over-all and placement sprays were also made one month later to grass regrowth following hoeing. The growth of grass was stopped by the over-all sprays, but the beets did not outgrow the dalapon symptoms by harvest time three months later. The placed spray gave excellent grass control with little visible effect on the beets.

In Michigan where quack grass (*Agropyron repens*) is a major problem, preplanting treatments with Dowpon have given promising control. Application rates of 5 to 20 pounds per acre applied in late fall or in early spring prior to plowing have given commercial control of quack. One disadvantage of spring treatment is the planting delay that is caused. Whether spring or fall application is employed, it is important to treat the grass when it is growing well and when it has sufficient foliage for adequate up-take of the dalapon. A delay of three days after spraying is adequate to obtain near-maximum herbicidal effect. It has been found that by combining tillage, i.e., plowing, with treatment, much improved results over dalapon application alone can be expected. In other tests, applications were made to beets as over-all treatments during the growing season and quack grass was stunted and reduced considerably, although not eliminated, using about 6 pounds of Dowpon per acre, and wetting the grass well.

In eastern Canada at the Experimental Station at L'Assomption, Quebec, dalapon was used pre-emergence at 8 pounds per acre for the control of grasses. Results were encouraging and good control was obtained. At the Lethbridge, Alberta, Experimental Station, results on green foxtail in beets over a two-year period were such that a recommendation was made to apply 2 to 4 pounds acid equivalent of sodium dalapon after the foxtail reached the 2 leaf stage. Both pre- and post-emergence sprays of Dowpon were suggested in the recommendations of the National Weed Committee for 1956.

Reports furnished The Dow Chemical Company by independent workers at Rocky Ford, Swink, and Fort Collins, Colorado, Huntley and Hardin, Montana, Salt Lake City, Utah, and Mason City, Iowa, reveal results for 1955 in which rates of 3-10 pounds Dowpon per acre were tested on sugar beets for control of grass. A general summarization indicates the results were favorable from the standpoint of killing or stunting the grass including foxtail grass, and tame and wild oats. Some leaf burn on the beets was noted by direct sprays of dalapon, but adverse effects on yields and sugar production were not reported.

Burtch[4] made investigations at Woodland, California, on the tolerance of varieties of sugar beets. Yields of all varieties were somewhat lower in the treated plots which were sprayed overall with dalapon, sodium salt at 4 pounds acid equivalent per acre. Late application, 3 months before harvest, was more drastic than application immediately following thinning. Placement sprays were not included in the experiments.

Preliminary data on the 1956 trials have been received from various cooperators. Loomis[5] conducted a test in California using a rate of 6 pounds Dowpon in 50 gallons water per acre. Directional and over-all sprays were applied July 9 to beets that had been planted March 15 and thinned May 10. Two weeks later, margins of recently matured leaves in the over-all spray plots showed necrotic areas. Beets which had received directed sprays showed only slight damage which was outgrown by September 9. On October 6, yield sampling was undertaken. Tonnage was low due to nematode infestation and virus.

Table 2 gives yields in tons of beets and tons of sugar for six replicates.

Table 2.—Results on Sugar Beets, in California, Sprayed at the Rate of Six Pounds Downpon Per Acre, 1956.

Treatment	Replicate						Mean
	1	2	3	4	5	6	
	Tons of Clean Roots per Acre						
Untreated	17.1	13.8	15.0	21.8	14.3	22.9	17.5
Directed spray	14.3	20.5	13.9	21.2	15.3	15.4	16.8
Over-all-spray	12.8	15.1	11.1	13.1	13.0	17.6	13.8
	Tons of Sugar per Acre						
Untreated	2.58	2.03	2.28	3.40	2.14	3.44	2.65
Directed spray	2.20	3.15	2.07	3.20	2.30	2.19	2.52
Over-all spray	1.89	2.14	1.61	1.74	1.82	2.50	1.95

The data show no consistent differences between the untreated beets and those which received six pounds of Dowpon per acre as a directed spray. Late application as an over-all spray on large plants, resulted in some yield reduction.

Bohmont[6] has reported results in Wyoming where grass control averaged 96 percent with eight pounds of Dowpon with no reduction in sugar beet stands. Yields in all locations averaged 20 and 22 tons respectively for the treated and untreated plots.

Through cooperative effort of The Great Western Sugar Company and The Dow Chemical Company, extensive field trials with Dowpon were completed in Colorodo and Nebraska. Dowpon was applied post-emergence at the two true-leaf stage of beets with a low volume, low pressure sprayer equipped with flat fan-spray nozzles. The width of the band was adjusted by raising or lowering the nozzles. The grass, mostly *Setaria viridis*, was

[4] Personal communication.
[5] Personal communication.
[6] Personal communication.

usually less than two inches tall. Yields and stands of beets were calculated from 20 samples per treatment per location. Results are summarized in Table 3.

Table 3.—Harvest Results Giving Stand, Yield and Sugar Percentage for Dalapon Treated and Non-treated Sugar Beets in Each of Nine Widely Separated Fields—1956.

		Dalapon Post-emergence			Check		
Location	Application[1]	Beets per 100 ft. of row	Tons/A	Sugar %	Beets per 100 ft. of row	Tons/A	Sugar %
Brighton, Colo.	1.5 lb/A in 6" band	75	19.47	14.30	77	20.27	14.85
Brush, Colo.	1.5 lb/A in 6" band	79	23.08	17.52	80	23.44	17.10
Sterling, Colo.	1.5 lb/A in 6" band	99	22.41	17.06	100	23.81	16.48
Ovid, Colo.	1.5 lb/A in 6" band	120	19.41	16.86	105	18.98	17.03
Bayard, Nebr.	1.5 lb/A in 6" band	109	11.30	17.77	108	11.49	17.76
Gering, Nebr.	1.5 lb/A in 6" band	140	19.73	16.93	132	20.19	16.19
Lyman, Nebr.	1.5 lb/A in 6" band	108	20.11	17.01	106	20.90	17.17
Eaton, Colo.	2 lb/A in 7" band	107	24.05	16.50	103	22.80	16.44
Longmont, Colo.	2.4 lb./A in 10" band	78	15.39	17.34	89	16.64	17.43
Longmont, Colo.	3.5 lb/A in 10" band	88	17.68	17.40	89	16.64	17.43
	Mean	100.3	19.26	16.87	98.9	19.52	16.79
	LSD 5% pt.	NS[2]	NS	NS			

[1] Amount of Dowpon sprayed over beet row prior to thinning. Equivalent rates broadcast would approximate 5.5 to 7 pounds per acre Dowpon or 4 to 5.2 pounds per acre dalapon equivalent.

[2] Mean value not significantly different from mean of check at indicated level.

None of the differences in Table 3 reached the 5 percent point of significance. While there was usually visible injury to beets following Dowpon application, recovery was good as indicated by the data on stand and yield.

The delayed action of dalapon on grass is becoming better understood. This chemical often affects and kills grass slowly, particularly under low temperature or other conditions favoring slow growth. Its action on grass is similar to the action of 2,4-D on broadleaved weeds. Even though stunted grass may remain green and even though some live grass seedlings are present at thinning, the job of weeding and thinning is greatly facilitated.

Registration[7]

The use of an herbicidal chemical on a food crop such as sugar beets, where residues may be present at harvest, is regulated by both the Federal Insecticide, Fungicide, and Rodenticide Act, and the Federal Food, Drug, and Cosmetic Act. In order to register the use of Dowpon on sugar beets under the Insecticide, Fungicide, and Rodenticide Act, residue determina-

[7] Use of Dowpon on sugar beets in accordance with label directions now has full clearance. A tolerance of five p.p.m. in roots and tops was established (Federal Register, January 3, 1957) and the recommended use of Dowpon will not result in a higher residue and is considered a safe and useful practice.

tions were required on both sugar-beet roots and tops collected from Dowpon-treated plots. The analytical determination of small amounts of a pesticide-chemical residue in a crop such as sugar beets was time consuming. The development of a satisfactory analytical method required about a year and the analysis of an adequate number of dalapon treated samples, both tops and roots, required many work weeks. However, the analyses have been completed as have also the toxicological studies which included chronic dietary feeding tests for two years with rats and one year with dogs. Residue determinations were made separately on beet roots and tops from Michigan, California, North Dakota and Montana. More than 50 percent of the samples of beet tops and 80 percent of the samples of beet roots showed less than 1 p.p.m. dalapon or essentially nil residue. The highest residues found in tops and roots were 4 p.p.m. and 2 p.p.m., respectively. A petition requesting a tolerance of 5 p.p.m. for dalapon in sugar beet roots and tops was accepted for filing by the Food and Drug Administration and an application for registration has been submitted to the U.S.D.A. It is anticipated that a tolerance and registration will be granted early in 1957 which will permit the use of dalapon on sugar beets for the 1957 and subsequent seasons.[7]

Analysis of Dalapon in Plant Tissue

The method for the analysis of 2,2-dichloropropionic acid or its sodium salt in biological materials is based on the conversion by hydrolysis to pyruvic acid, the latter then being estimated colorimetrically as the 2-4-dinitrophenylhydrazine derivative.

In order to carry out this procedure, it is necessary to first isolate the 2,2-dichloropropionic acid from naturally occurring a-keto acids and other compounds which will be converted to a-keto acids during the hydrolysis reaction. The sample is acidified to insure conversion of the sodium 2,2-dichloropropionate to the acid form. The organic acids and other ether-soluble compounds are removed from the sample by continuous ether extraction. The acidic compounds can then be extracted from the ether with a sodium hydroxide solution. The a-keto compounds present in this solution are removed by converting them to their corresponding 2,4-dinitrophenylhydrazone derivatives and then passing the solution through a siliconized super cel (a diatomaceous earth) column saturated with benzyl alcohol. The hydrazones remain on the column while the 2,2-dichloropropionic acid and other constituents pass through. Since each component in the system will pass through the column at a specific rate, additional separation of the components can be obtained by taking cuts of the effluent from the column and saving only those known to contain the dichloropropionic acid.

The dichloropropionic acid can further be separated from interfering substances by heavy metal precipitation using copper sulfate and calcium hydroxide. Under these conditions the interfering substances are precipitated while the dichloropropionic acid remains in solution.

The dichloropropionic acid is then converted to pyruvic acid by hydrolysis. Once the pyruvic acid has been formed, it can be measured by the standard colorimetric procedure used for estimating this acid in biological materials.

Brief Statement on Toxicology of Dowpon

Dalapon, sodium salt (Dowpon) is one of the least toxic and one of the safest of the many chemicals used in agriculture today. It is low in systemic toxicity; ingestion or inhalation of small amounts, such as might be encountered when the material is used as recommended, do not constitute a hazard to health. The feeding of single doses to various species of animals, including mice, rats, guinea pigs, rabbits, chicks, and steers has shown the material to be less toxic acutely than ordinary table salt. The acute oral LD_{50} values for these species range from 3 to 8 grams per kilogram of body weight.

Studies have been conducted to determine the effect of feeding Dowpon repeatedly to rats, dogs, and cattle. These studies have shown that rats can tolerate, without effect, a dosage level between 15 and 50 mg./kg./day for two years; that dogs can tolerate without effect for at least one year, daily doses of at least 50 mg./kg.; and that a bull suckling calf tolerated without effect a daily dose of 1000 mg./kg. on 10 of 11 successive days. Lake Emerald Shiners were maintained for three days in water containing 3,000 p.p.m. by weight of the material without apparent adverse effect; 5,000 p.p.m., however, was lethal. This illustrates probably low toxicity to fish although the reactions of other species have not been determined.

These observations emphasize the low degree of systemic toxicity of Dowpon. Furthermore, Dowpon is not likely to cause irritation of the skin unless exposure is unusually severe, that is, prolonged or frequently repeated. The probability that exposures of short duration will be injurious is small. The ability of the material to cause irritation is markedly reduced by dilution; hence, the prompt flushing of exposed areas with water essentially eliminates the possibility of irritation occurring. The material is not absorbed through the skin to any appreciable degree, if at all. It does not present a serious hazard of eye injury. If contact occurs, plain and irritation can be expected but serious injury is not probable, particularly if the contaminated eye is promptly and thoroughly flushed with flowing water.

The experience gained in manufacturing, handling, and using Dowpon has borne out the conclusion that it does not present any serious handling hazards.

Conclusions on Performance and Use of Dalapon

1. Dalapon is a useful tool in controlling grass in sugar beets.

2. It is effective against most seedling grasses including wild oats when applied post-emergence and also against certain perennial grasses like quack grass when used in pre-planting applications. Pre-emergence application can be effective against seedling grasses.

3. Dalapon can temporarily affect beets adversely under some growing conditions, but where a grass problem is severe, this temporary effect is more than compensated for by the increased growth and yield due to the control of the grass and by the comparative ease of subsequent production practices.

4. Normally, a foliage application of 4 to 6 pounds Dowpon (sodium dalapon) on seedling grasses is adequate and safe. In some areas where relatively high temperatures are likely to occur at the time of, and following spraying, the effect on the beets may be more pronounced than in areas where lower temperatures prevail.

5. Results in California seem to indicate that it may be advisable to use placement sprays to decrease the beet response.

6. Dalapon, as Dowpon, is finding its place as a sugar beet herbicide and should aid in the realization of a complete mechanization program for sugar beet production.

7. Suggestions for use of Dowpon are: To control water or barnyard grass, foxtail or pigeon grass, and other grass seedlings, use 4 to 6 pounds per acre of Dowpon (over-all treatment) in sufficient water for good spray coverage of the grass. Band treatment may be used with a proportionate reduction in the amount of Dowpon per acre of beets. Application may be made from the time of beet emergence until the beets are in the 4 leaf stage. For best results, the grass seedlings should be small. Older seedlings and wild oats (*Avena fatua*) are more tolerant and may require 7 to 9 pounds for most effective control. Rates above 6 pounds per acre may cause some yield reduction. In cases where such rates are needed, and in certain areas having relatively high temperatures during the application period, the use of directed sprays after thinning is suggested so that the grass foliage is sprayed without spraying the beet foliage. Dowpon acts slowly, and a 2 to 3 week interval after spraying may be required before grasses die. Thinning operations may be started 7 days after Dowpon application, if desired.

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Depolymerization of Paraformaldehyde

R. E. HALLBECK[1]

Formaldehyde in solution is commonly used to control microbiological growth in continuous diffusers. The solid polymer, paraformaldehyde, can be depolymerized and a resultant formaldehyde solution obtained which will serve the same purpose as formalin in the continuous diffusers.

Paraformaldehyde of commerce is a mixture of chain polymers of formaldehyde of high molecular weights (1)[2]. It is a white, crystalline powder. It is only slowly soluble in cold water, but more readily soluble in hot water, with evolution of formaldehyde. Paraformaldehyde is 90 to 95 percent available formaldehyde.

One unit of formaldehyde derived from paraformaldehyde will cost about 57 percent as much as one unit of formaldehyde in formalin, before freight. Costs as delivered to our Spreckels Factory further increases the spread to 50 percent.

It is not desirable to use paraformaldehyde in a solid state directly introduced to the diffuser, though this would seem easiest, because solution and depolymerization of the paraformaldehyde proceed slowly under the conditions generally prevalent in cells of the diffuser when treatment for microbobiological control is required. Consequently formaldehyde concentrations, high enough to effect maximum bacteria kill, may not be attained, unless an excess of the bactericide is introduced.

It then is suggested to depolymerize the paraformaldehyde and introduce the resultant formaldehyde solution into the diffuser. Various means were proposed.

According to Peterson (2), the solubility of formaldehyde polymers in water is increased in the presence of methenamine. This was verified for concentrations up to 1 percent of methenamine. Toxicity of this chemical made it unattractive in application.

Depolymerization by vaporization using a jet of steam was considered and discarded since only a trace of moisture will cause polymerization of formaldehyde vapor in the 100° C. temperature range.

Miller (3) holds a patent which provides for generation of pure, monomeric formaldehyde by introducing a suspension of paraformaldehyde in a liquid carrier having a vapor pressure not in excess of 15 mm. Hg. at 200° C. The formaldehyde flashes out leaving the carrier unchanged. Caster oil makes a satisfactory carrier. The process was considered as too elaborate for our requirements.

Paraformaldehyde will depolymerize and go into a 25 percent formaldehyde solution in boiling water in about five minutes with adequate

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[2] Numbers in parentheses refer to literature cited.

circulation. At this temperature considerable formaldehyde is lost in vapors. Adequate venting of vapors to prevent discomfort and injury to personnel is a problem. Depolymerization and solution rates fall off rapidly with decreasing temperatures to a point where a 1 percent solution is obtained in 20 minutes at room temperature.

The polymer was reported to be soluble in dilute alkali hydroxide solutions. Experimental work conducted by Spreckels chemists at Woodland showed that at room temperatures the concentration of a formaldehyde solution prepared from paraformaldehyde could be increased from about 1 percent at 8 pH to 22 percent at 12 pH. These monomeric formaldehyde concentrations were reached in 20 minutes contact time, with agitation.

Further laboratory tests indicated that 100 grams of paraformaldehyde dissolved completely in 300 ml. of water in 20 minutes, at 60° C., with agitation and when 0.1 percent NaOH on paraformaldehyde had been used.

At this point a test in the Woodland Factory was made. A solution of 100 pounds of paraformaldehyde was prepared by adding 3 ounces of caustic to 140 gallons of house hot water at 90° C., then adding the paraformaldehyde while stirring. Steam for heating was turned on for 1½ minutes and the resultant temperature of the mixture was 70° C. Depolymerization was complete in 23 minutes and the temperature then was 64° C. The caustic added had raised the house hot water to 10 pH.

For routine factory practice depolymerization and solution of paraformaldehyde has worked out as follows:

Equipment: A tank of about 200 gallons capacity (which should be covered and provided with a vent to the outdoors if located indoors); a

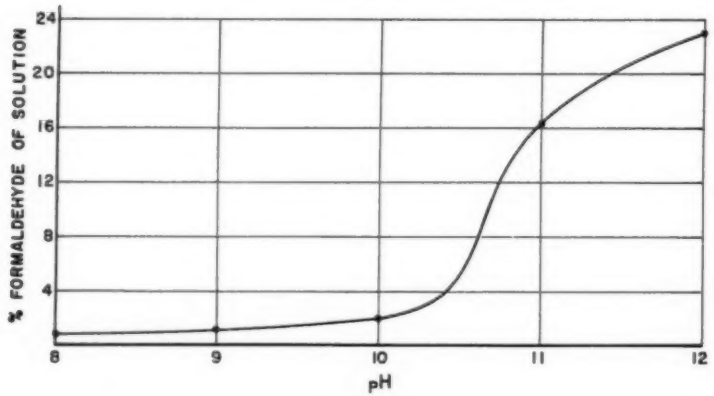

Figure 1.—Effect of water pH on depolymerization of paraformaldehyde. Percent formaldehyde by weight in solution, after 20 minutes at room temperature is plotted against pH of water.

water supply to tank; provision for heating by steam injection; provision for agitation such as a Lightnin' mixer; pump and lines to carry formaldehyde to desired points of application.

The diffuser operator prepares a new solution as the tank becomes empty. One hundred fifty pounds of paraformaldehyde are mixed with about 160 to 165 gallons of water, with sodium hydroxide added to bring the pH to 10.5. The mixture is heated by steam injection to 40° C., and agitated. Nearly complete dissolution is reached in about 30 minutes. The solution thus prepared will be approximately 10 percent formaldehyde.

By increasing the solution temperature or increasing the pH, the solution rate of paraformaldehyde may be increased. Similarly, the formaldehyde solution concentration may be increased. Figure 1 depicts a plot of pH versus paraformaldehyde solution.

Feasibility of depolymerization of paraformaldehyde has resulted in important savings in the cost of diffuser bacteria control.

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A Preliminary Evaluation of Precision Hill Planting of Sugar Beets

DAVID RIRIE, F. J. HILLS, AND R. A. KEPNER[1]

Recent work at Davis has indicated that stands containing 50 percent doubles and 25 percent multiples (3 or more beets) did not reduce root or sugar yield when a 12-inch spacing was maintained between beet hills (4)[2]. This led to the concept that thinning might be eliminated, or the labor requirements substantially reduced, by planting groups of seeds in hills spaced 8 to 12 inches apart. In this manner, a reasonably high seeding rate could be maintained and, depending on the degree of field emergence, thinning might be eliminated or reduced to a long-hoe operation. A preliminary experiment to test this procedure was conducted at Davis, California, in 1955; the results are reported herein.

Procedure

Standard blank plates for a John Deere Model 66 planter were drilled to establish the desired hill spacings. The distance between adjacent cells was the same as for the regular 72-cell plate. For one set of plates, 3 consecutive cells were drilled, the next five spaces were left blank, then 3 more drilled, and so on around the plate. For another set, 5 cells were drilled, 7 skipped, and so on. A gear ratio was selected to place the seeds 1 inch apart within the hills. This gave center distances of 8 inches and 12 inches for the 3-seed and 5-seed hills, respectively, and an average of about 5 seeds per foot of row in each case. With standard 72-cell plates and the same gear ratio, 12 seeds per foot were planted in the control plots for hand thinning to an ideal stand. Another gear ratio with the 72-cell plates gave a theoretically uniform spacing of single seeds, 2.6 inches apart, for the same number of seeds per foot as with the hill plantings. The same planter was used for all plots.

The seed was of the variety US 22/3, processed and graded to 7-10/64 inch. The six treatments indicated in Table 1 were arranged in a randomized block design with six replications. Individual plots were 4 rows wide by 80 feet long. Seedling emergence was good. Accurate counts were not made to indicate emergence, but from counts made on unthinned plots later in the season, emergence was estimated at from 40 to 50 percent.

About three weeks after thinning, stand counts were made on the center 25 feet of all four rows of each plot. These counts reflected the number of four-inch blocks containing single, double, and multiple plants, as well as total length of unoccupied row in excess of 16 inches per gap. This procedure for stand evaluation has been reported in another paper (3) and is discussed further below.

Harvest data were taken on the center 50 feet of each plot. Beets two inches or less in diameter were counted, weighed, and discarded as unmarketable. The remaining roots were counted and weighed as marketable. For sucrose and tare determination, four samples were taken from each plot.

Results were evaluated by analyses of variance. The relationships of certain stand factors to root yield were determined by multiple correlation analysis (1).

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[2] Numbers in parenthesis refer to literature cited.

Table 1.—Effect of Seed Distribution Pattern and Long-Handled-Hoe Thinning on Yield, Stand, and Percent Sugar, Davis, California, 1955.

Treatment Number	Theoretical Distribution of Seed by Planter: Seeds Per Hill	Theoretical Distribution of Seed by Planter: Hill Spacing, Inches	Thinning Treatment	Stand After Thinning Number of 4-inch Blocks Per 100 Feet: Singles	Doubles	Multiples	Total	Percent of Row Unoccupied	Yield of Clean Beets (Over 2 Inches Diameter), Tons Per Acre	Sugar Content, Percent	Stand at Harvest: Beets Greater Than 2 Inches in Diameter: Number Per 100 Feet	Stand at Harvest: Beets 2 Inches or Less in Diameter: Number Per 100 Feet	Stand at Harvest: Beets 2 Inches or Less in Diameter: Percent of Total Number	Stand at Harvest: Beets 2 Inches or Less in Diameter: Tons Per Acre
1	1	1[1]	short hoe	135	14	1	150	0.6	29.4	14.9	156	9	5.4	0.2
2	1	2.6[1]	none	53	49	50	152	1.1	23.9	15.3	216	97	31.0	2.3
3	5	12	none	28	30	56	114	2.5	23.0	15.1	202	79	28.1	1.9
4	3	8	none	44	42	40	126	3.2	25.7	15.1	201	45	18.3	1.2
5	5	12	long hoe	59	33	14	106	1.2	28.7	15.1	150	14	8.5	0.4
6	3	8	long hoe	67	38	10	116	2.4	28.8	15.0	159	19	10.7	0.6
Significant differences, 19:1						9		1.7	1.9	ns.[4]	19	23		0.4
Partial correlation coefficients[2]						—0.789[3]		0.219						
Regression equation[3]				Y = 29.77 — 0.202 Xg — 0.101 Xm										

[1] Single seeds, uniformly spaced.
[2] Based on multiple correlation of tons per acre with multiples (Xm) and percent row unoccupied (Xg) Y = Yield in tons roots per acre.
[3] Significant at odds of 999:1
[4] Not Significant

Results and Discussion

All results are reported in Table 1. With seeds uniformly spaced 2.6 inches apart and the stand not thinned, the root yield was 5.5 tons per acre less than in the plots that were carefully thinned to almost all singles spaced 8 inches apart. The unthinned plots with 5-seed hills on 12-inch centers showed a similar reduction of 6.4 tons per acre. With 3-seed hills on 8-inch centers, the yield reduction was only 3.7 tons per acre, which was significantly better than the yield produced by the 5-seed hills. Beets planted by both hill spacing methods, when thinned with long-handled hoes, produced yields essentially equal to that produced by carefully hand-thinned beets. None of the treatments had a significant effect on sucrose percentage.

The three unthinned treatments, all averaging approximately 5 seeds per foot (treatments 2, 3, and 4, in Table 1), produced essentially the same number of beets greater than 2 inches in diameter at harvest. The lower root yield of treatments 2 and 3 are apparently due to smaller average root size. The higher yield produced by treatment 4 was accompanied by a lower percentage of unmarketable beets when compared to treatments 2 and 3.

In considering the effect of stand on root yield, there are two obvious factors that can cause yield reduction, namely: crowding plants too close together, and excessive row space not occupied by plants. Based on other experiments at Davis (3), a 4-inch space was selected as the criterion for determining "too close." Adjacent plants spaced 4 inches or greater were counted as singles, whereas two plants in a 4-inch space were considered a double, and three or more within a 4-inch length were multiples. To evaluate skips in stand, Demings' procedure for calculating percent of row unoccupied was used (2). In this procedure, only skips greater than 16 inches are considered; the unoccupied length of each gap being taken as the actual gap length less 16 inches. The unoccupied lengths thus determined are accumulated to determine feet of row unoccupied per 100 feet. Based on the counts shown in Table 1, there is no consistent relation between root yields and either singles or doubles. As noted above, emergence in this trial was good, consequently multiples are high and row unoccupied is low. Perhaps the only truly significant difference among the treatments with respect to row unoccupied is between hand thinning and the hill-planting treatments. Even this difference is minor. Root yields, however, are closely associated with differences in the number of multiples. A multiple correlation analysis relating the root yield of individual plots to determinations made for each plot for multiples and row unoccupied indicates a highly significant negative correlation between root yield and multiples. The correlation coefficient for row unoccupied is low, indicating that in this trial, row unoccupied was a relatively unimportant factor in yield reduction. When estimated values for root yield are calculated, using the treatment averages for multiples and percent row unoccupied in the regression equation given in Table 1, values for root yield are obtained that closely approximate those actually observed.

In this experiment, the effect of hill planting upon the ease of long-handled hoe thinning was not evaluated. It would seem, however, that stands obtained by precision hill planting should be considerably easier

to thin than stands obtained by planting in the conventional manner. The fact that the basic hill spacing is already established (see Figure 1) should eliminate many of the decisions of the thinner as to which plant to leave, thereby speeding up the work and enabling him to do a job of higher quality. Under conditions of less favorable field emergence, little or no trimming may be needed. Based on experience to date, it would appear that multiple hills up to 20 per 100 feet of row will have little effect on yield (3), (4).

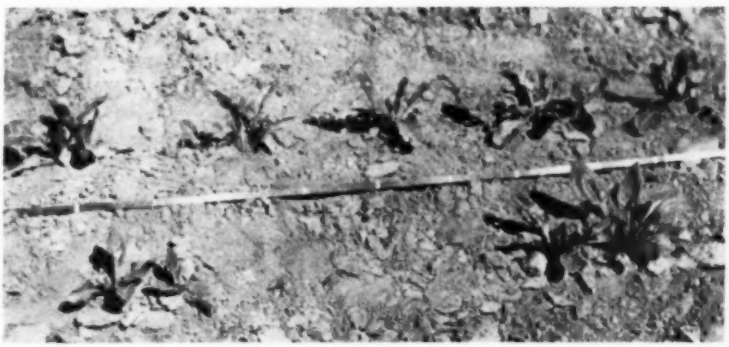

Figure 1.—Unthinned stand of 3-seed hills on 8-inch centers. Such a stand is easily thinned with long-handled hoes. The white marks on the tape between the two rows are 4 inches apart.

Summary

A field experiment was conducted to evaluate the effect of precision hill planting on sugar beet yields, using specially-drilled seed plates in a John Deere Model 66 planter. Two hill distribution patterns were employed: (a) 3 seeds 1 inch apart within each hill, with 8-inch hill centers, (b) 5-seed hills on 12-inch centers. With each of the two hill planting patterns, some plots were untrimmed and others were trimmed with long handled hoes. Yields were compared with those from plots that had been planted in the conventional manner and carefully hand thinned.

In these trials, field emergence was excellent, resulting in 40 to 60 hills of 3 or more plants per 100 feet of row. There were very few skips in any of the stands. Under these conditions, both hill planting patterns, when not thinned, reduced root yields in comparison with yields from hand-thinned beets. The yield reduction was less with 3-seed hills on 8-inch centers than with 5-seed hills on 12-inch centers. Long-handle-hoe trimming of both hill spacings resulted in yields essentially the same as that obtained with hand-thinned plants and reduced multiples to an average of 10 to 14 per 100 feet of row. There was a high negative correlation between root yield and the number of multiple-plant hills.

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Inheritance of Chlorophyll Deficiencies in Beta Vulgaris L.

V. F. Savitsky[1]

Introduction

The inheritance of chlorophyll deficiencies in sugar beets, including plastid inheritance, has attracted the attention of scientists because many problems in genetics and physiology of sucrose content and root yield can not be solved by studies restricted to the root.

Discussions concerning the localization and the synthesis of sucrose in beets (21, 30)[2] and also the forms of the mobile sugar in the vascular system rest on the new facts showing that the synthesis of sucrose is localized in leaves but not in the petiole or in the tops of the roots. In experiments where radioactive-marked carbohydrates ($C^{14}O_2$) were used for nutrition, it was indicated that when beets were exposed to light the radioactive carbohydrates appeared first in the formation of sucrose in the leaf blades. This made it possible to consider sucrose as principal mobile sugar built during photosynthesis directly in leaves, but not in the roots of sugar beets (21, 22, 30).

The intensity of photosynthesis depends upon different structures of plastids which vary during the ontogenetic development of the plants (45). The sugar beet root contains, even in the internal tissues, some colorless leucoplasts, as well as green chloroplasts (10). The function of plastids in the root tissues is unknown.

Experiments in beets (41), barley (12), and other crops showed that genes causing chlorophyll deficiency changed the size, color, and number of plastids in the leaf cells. In this way such genes also changed the intensity of photosynthesis, and in connection with this, they could acquire a pleiotropic action on the development of certain quantitative characters in beets.

In Antirrhinum (44), barley (13, 14, 15), and sorghum (20) certain genes which cause chlorophyll deficiency in the homozygote showed general heterosis in the heterozygote.

Different chlorophyll mutations were observed in plants after exposure to atomic radiation (17, 36).

Knowledge of the inheritance of chlorophyll deficiency in beets is necessary for the genetic and physiological study of beets as well as for breeding work, especially for the breeding of irradiated beets.

Material and Methods

The chlorophyll-deficient races studied were isolated in varietal populations of sugar and fodder beets, inbred lines, and hybrids. In this way they all represented natural mutations but not mutations stimulated by X-rays, radiation, etc.

Hybrids were obtained by exchanging pollinating paper bags. F_2 seed was obtained by selfing or from sib-matings of F_1 plants. To study the in-

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[2] Numbers in parentheses refer to literature cited.

heritance of the small differences in the quantity of chlorophyll, the parental plants were propagated vetgetatively. Clones were vegetatively propagated for several years, which made it possible to obtain F_1 and F_2 seed and to produce backcross hybrids.

Linkage between genes causing chlorophyll deficiency and other genes known in *Beta vulgaris L.* will not be discussed in this paper.

Experimental Results

The inheritance of albinism. The study of albinism in beets was started by Proskowetz (35). During 1885 and 1886 Proskowetz studied seventeen chimeric plants with alternate green and white sectors. He came to the conclusion that albinism was partially inherited.

Non-Mendelian inheritance of chlorophyll deficiency, *status albomaculatus*. In 1919 Stehlik (43) found a variegated seed beet which developed one green and one white branch. The seedlings grown from the seed balls collected from the white branch were yellow. He concluded "Das diese gelbe Farbung von dem in den Zehlen vorhandenen Farbstoffe der chromatophoren berruhrte." ("That this yellow color was caused by the color of chromoplasts located in the cells.") These plants could not develop chlorophyll and perished at an early stage. The plants derived from seed balls of the green branch gave 600 normal green plants without any trace of albinism. Stehlik was the first to state that albinism in varietgated beets was inherited through the cytoplasm, as shown from studies in *Mirabilis Jalapa albomaculata* by Correns in 1909 (8).

Stehlik's conclusions that albinism in beets is inherited through the cytoplasm only, was confirmed by Munerati in 1928 and 1942 (25, 26). Munerati indicated that the chimeric variegated beets occurred in populations at the rate of one per 30,000 or 40,000 green plants. To study the inheritance of albinism, Munerati collected about 300 chimeric plants per year in commercial varieties.

The progeny consisted of white seedlings exclusively when the flowers from the white branches or green branches.

Seed collected from the green branches in the first generation, as well as in five subsequent generations, produced normal green plants independently of whether they were derived from hybridization by pollen collected from white or green branches. Therefore, Munerati concluded that albinism in beets in inherited through the cytoplasm only as it is inherited in *Mirabilis Jalapa albomaculata* (5 and 6), *Primula sinensis* (11 and 46), and in *Zea mays* (3).

In 1940 Owen and Ryser (32) also described one case of cytoplasmic inheritance of albinism from studies of the progeny from white and green branches of "partially albino plants."

I have studied many progenies of chimeric variegated plants isolated in sugar and fodder beet populations. Among these progenies only one authentic case was established where albinism was caused by a change in the nuclear gene. In all other cases the chimeric plants appeared as a result of heritable changes in the cytoplasm.

It is interesting to note that among several thousand plants known to be heterozygous for recessive genes causing chlorophyll deficiencies, I have never observed chimeric plants. Thus, chimeric variegated plants occurred

in beet populations more often as a consequence of heritable changes in the plasm rather than as a result of mutation of nuclear genes. This type of albinism, because of its comparatively frequent appearance, attracted the attention of the first investigators (25, 35, 43).

In a review of the inheritance of chlorophyll deficiencies in which a resume of all investigations conducted in all crops to 1933 was cited, H. de Haan (16) mentioned, for *Beta vulgaris,* only one type of chlorophyll deficiency—Mirabilis type (*status albomaculatus*).

Mendelian inheritance of albinism—the gene w_1. In 1928, among seed beets of Yellow Eckendorf, I found one variegated plant (4, 41). The pollen collected from flowers of the white and of the green branches of this plant was used for pollinating normal green sugar beets. F_1 plants developed colored roots and green foliage. F_2 hybrids segregated for characters typical of sugar and fodder beets as well as the presence or absence of chlorophyll in seedlings.

In F_2 hybrids derived from pollination of normal green sugar beet plants by pollen collected from white branches of a variegated plant, there appeared 256 green and 79 albino seedlings. The color of these albino seedlings corresponded to the "maize yellow" of Ridgway (37).

In F_2 hybrids derived from pollination of green sugar beets by pollen collected from the green branches of the same variegated plant, only certain families segregated for albino seedlings in the ratio of three green to one albino. In this way the green branches of this variegated plant were heterozygous for the recessive gene causing chlorophyll deficiency.

Some F_3 lines obtained from green F_2 plants segregated again for green and white seedlings in the monohybrid ratio (Table 1). Thus, the variegated Eckendorf plant was heterozygous for the recessive gene which I denoted as w_1. This gene produced albino seedlings in the homozygote. The chimeric nature of the original heterozygous variegated Eckendorf plant was caused by the mutation of the dominant gene *W* into a recessive gene *w*.

Recessive genes causing complete albinism of seedlings are considerably rarer in beets than the other recessive genes for chlorophyll deficiencies, as for example the genes virescens, chlorina, etc.

Table 1.—Mendelian Inheritance of Albinism in *Beta Vulgas* L.

	Number of Seedlings		
	Green	White	χ^2
In F_2			
Observed	256	79	
Calculated (Ratio 3:1)	251.25	83.75	0.359
In F_3			
Observed	778	247	
Calculated (Ratio 3:1)	768.75	256.25	0.445

5% point of probability $\chi^2 = 3.84$
1% point of probability $\chi^2 = 6.64$

Sometimes the appearance of albino seedlings may be caused by some other genes, for example, by the dominant gene Aurea or by the action of two non-allelomorphic genes.

In F_2 hybrid lines the albino seedlings appeared sometimes in the ratio of one to 15 normal green plants. In such a case we had to deal with true duplication of genes causing albinism as described in other crops (7).

Aurea type—the dominant gene *Au*. In a population of U.S. 22/3 I found one plant which developed golden-yellow cotyledons (Baryta yellow in Ridgeway's 'Color standards") and subsequent true leaves of the same color. If conditions for growth were favorable the heterozygous plants *Auau* developed normal green autumn leaves. Genetic study of the progenies obtained from this plant proved that the given type of chlorophyll deficiency was caused by the dominant gene *Au* with lethal effect in the homozygote. The homozygous seedlings were albino. A similar gene was described by Bauer (5, 6) in *Antirrhinum* and in *Pelargonium* and by Correns (9) in *Utrica urens*. This gene is known in other crops too. Table 2 shows the data of genetic analysis of the gene *Au* during 1953, 1954, and 1955.

When normal green plants were crossed to plants of a given type of chlorophyll deficiency, the F_1 always was not uniform; green and yellow seedlings appeared in the ratio of 1:1. Selfed F_1 green plants produced, in all subsequent generations, uniformly green offspring, but the F_2 progenies from selfed yellow F_1 plants segregated for green, yellow, and albino seedlings in the ratio of 1:2:1 (Table 2).

Table 2.—Inheritance of Aurea Type in Sugar Beets.

	Generation	Year	Number of lines	Seedlings			χ^2
				Green	Yellow	Albino	
Observed	F_1	1953	8	529	522	—	
Calculated (ratio 1:1)				525.5	525.5	—	.0047
Observed	F_1	1954	7	244	241	—	
Calculated (ratio 1:1)				242.5	242.5	—	.0019
Observed	F_1	1955	4	111	103	—	
Calculated (ratio 1:1)				107	107		.0029
Observed	F_2	1953	14	516	1129	591	
Calculated (ratio 1:2:1)				559	1118	559	5.246
Observed	F_2	1954	7	181	343	183	
Calculated (ratio 1:2:1)				176.75	353.50	176.75	0.696
Observed	F_2	1955	7	103	184	101	
Calculated (ratio 1:2:1)				97	194	97	1.05

1% point of probability for F_1 generation $\chi^2 = 6.64$
1% point of probability for F_2 generation $\chi^2 = 9.21$

Lutescens type—gene *lu*. The recessive gene *lu* was isolated in hybrids between sugar and fodder beets, Red Eckendorf N 6219. The hybrids were propagated by sib-mating (41) (Table 3). In homozygous *lulu* plants the cotyledons and sometimes the first and second pair of leaves also showed normal green color. But subsequent leaves became more and more a lighter yellow. The majority of such homozygous yellow plants died. In surviving plants the root weight was reduced and did not exceed six percent of the root weight in normal green plants of the same hybrid. The F_1 plants were completely normal.

Virescens type—the genes *vi_1*, *vi_2*, and *vi_3*. In beet races of virescens type, development of chlorophyll is delayed. Seedlings of these races are golden-yellow (Martius yellow in Ridgway's "Color Standards") because of the presence of carotene and of xanthophyll. Chlorophyll accumulates later. The first leaves are light green, but the following leaves become greener and greener under greenhouse conditions and eventually, they can not be distinguished from leaves of normal green beets.

In the species *Beta vulgaris* numerous genes of the virescens type are dispersed. These genes are distinguished by the grade of delayed action of chlorophyll accumulation and, in connection with this, in the grade of viability and of productiveness of plants.

Table 3.—Inheritance of Lutescens Type in Sugar Beets.

	Number of Plants with Second and Third Pairs of Leaves Colored as follows:		
	Green	Yellow	χ^2
Observed	270	83	
Calculated	264.75	88.25	0.416

5% point of probability $\chi^2 = 3.84$
1% point of probability $\chi^2 = 6.64$

Table 4.—Segregation in F_2 After Crosses of Two Races of Virescens Type (*Vi_1 Vi_1 v_2 v_2* and *v_1 v_1 V_2 V_2*) of chlorophyll deficiencies in *Beta vulgas* L.

	Number of F_2 Plants Surviving		
	Green	Yellow	χ^2
Observed	434	290	
Calculated (ratio 9:4)	501	223	2.857

1% point of probability $\chi^2 = 6.64$
5% point of probability $\chi^2 = 3.84$

All these genes are recessive. They belong to different loci. When two different virescens races are crossed, the F_1 seedlings are normal green in color. In F_2 dihybrid segregation was observed (41). The double homozygotes ($vi_1vi_1vi_2vi_2$) were albino and perished because of their inability to accumulate chlorophyll. Plants homozygous in Vi_1 gene and heterozygous in gene Vi_2 ($vi_1vi_1Vi_2vi_2$) were also non-viable. Therefore, at the time of harvest, the segregation showed nine green to four yellow plants (Table 4).

The weight of root in these surviving yellow plants at harvest was 43.0 percent of the weight of root of the normal green plants in the same F_2 hybrids.

Every virescens gene *vi*, when it is separated from other virescens genes, showed mono-hybrid segregation in the ratio of three to one. In such cases there was no continual deficiency of plants with recessive genes in beets, the same as observed by Lamprecht (23) in peas.

In the past few years I isolated at the Salt Lake City station another gene vi_3, the homozygotes of which showed a still stronger delay in chlorophyll development than the previously described genes vi_1 and vi_2. Table 5 illustrates the inheritance of the gene vi_3. Observations were conducted for three years. The F_1 plants were normal green. In the F_2 generation mono-hybrid segregation was observed.

Table 5.—Inheritance of Virescens Type Deficiency (gene *Vi₃Vi₃*) in *Beta vulgaris* L.

	Year	Genera-tion	Number of Popula-tions	Number of Seedlings		χ^2
				Green	Yellow	
Obesrved	1954	F_1	3	89	—	
Observed	1952	F_2	1	317	103	
Calculated (ratio 3:1)				315	105	0.0507
Observed	1953	F_2	7	343	125	
Calculated (ratio 3:1)				351	117	0.729
Observed	1954	F_2	3	161	62	
Calculated (ratio 3:1)				167.25	55.75	0.9342
Observed	1955	F_2	6	218	89	
Calculated (ratio 3:1)				230.25	76.75	2.6069
Observed	1955		1	25	19	
Calculated (ratio 1:1)		backcross		22	22	0.8181

5% point of probability $\chi^2 = 3.84$
1% point of probability $\chi^2 = 6.64$

Variegated chlorophyll deficiencies—the genes v_1, v_2 and v_3. Variegated chlorophyll deficiencies are based on a recessive-pattern gene. A variegated gene was observed in beets by Owen and Ryser (32). Their description of this gene is as follows: "Variegated foliage, white with irregular blotches of green. Viability fair if seedlings are not crowded. Vigor not reduced in early cotyledon stage because cotyledons develop normally without chlorophyll deficiency. Leaves lack chlorophyll and plant vigor is decidedly reduced, but many v_1 plants have flowered and produced seed. Experience shows considerable instability at the v_1 locus."

The data for segregation in F_2 and in backcross hybrids given by Owen and Ryser showed a deficiency of variegated plants compared to normal green.

Abegg (1) found another variegated gene in beets v_2, the gene which causes variegated cotyledons: "Light green to normal green sectors."

The third gene v_3 was indicated by Abegg (1): "Variegated foliage. Yellow to normal green sectors." The inheritance of this gene was not shown.

The variegated chlorophyll deficiencies which develop in the presence of a mutable gene have been described in several species (18, 19, 33, 36). Similar genes were not found in *Beta vulgaris*.

Chlorina type—genes *ch*$_1$ and *ch*$_2$.—The genes causing chlorina type defects of chlorophyll in beets are recessive in the seedling stage. The decrease of chlorophyll is typical of the homozygotes—*chch*. The cotyledons, seedlings, and all new leaves in homozygous *chch* beets are light green until fall (Cosse green in Ridgway's "Color Standards"). The homozygous *chch* plants were viable, although the weight of their roots was reduced.

Table 6.—Inheritance of Chlorina Type Deficiency in *Beta vulgas* L.

	Year	Generation	Number of Families	Number of Seedlings		χ^2
				Green	Yellow	
Gene *ch* isolated in US 35/2						
Observed	1953	F_2	5	198	68	
Calculated (ratio 3:1)				199.5	66.5	0.0451
Observed	1954	F_2	3	101	40	
Calculated (ratio 3:1)				105.75	35.25	0.8534
Observed	1955	F_2	6	294	109	
Calculated (ratio 3:1)				302.25	100.75	0.4764
Observed	1955	F_2	7	311	112	
Calculated (ratio 3:11)				317.25	105.75	0.4925
Gene *ch* isolated in Great Western beet						
Observed	1954	F_1	1	63		
Observed	1955	F_2	9	440	135	
Calculated (ratio 3:1)				431	144	0.7101
Gene *ch* isolated in Kleinwanzleben beet						
Observed	1955	F_2	1	53	22	
Calculated (ratio 3:1)				56.25	18.75	0.7511
Gene *ch* isolated in red mangel beet						
Observed	1955	F_2	1	116	37	
Calculated (ratio 3:1)				114.75	38.25	0.5446

5% point of probability $\chi^2 = 3.84$
1% point of probability $\chi^2 = 6.64$

Certain chlorina-type genes differ in the grade of reduction of the weight of the root. For example, the gene ch_2, which was isolated in the variety U.S. 35/2, reduced the yield of roots about 20 percent. Another gene ch_1, which I found earlier (41), decreased the root weight much more.

The homozygotes ch_2ch_2, which were isolated in the inbred line SLC 378 *mm* remained light green for three years. The F_1 hybrids ch_2ch_2 normal green beets as well as the reciprocal hybrids were always normal green in the seedling and rosette stages.

The F_2 hybrids between ch_2 and different sugar beet varieties showed normal monohybrid segregation in 1953, 1954, and 1955 (Table 6).

Dr. H. E. Brewbaker and Dr. R. K. Oldemeyer of the Great Western Sugar Company kindly provided some plants with light green foliage which were found at the Experiment Station in Longmont, Colorado. I crossed these beets to normal green plants and to chlorina type beets SLC 378 *mm*. When beets of the chlorina type, which I received from Longmont, were crossed to normal green plants, the F_1 plants were normal green and the F_2 hybrids showed mono-hybrid segregation (Table 6).

When beets of the chlorina type from Longmont were crossed to chlorina type beets SLC 378 *mm*, the F_1 plants were not distinguishable in color of cotyledons and leaves from the two parental types. In F_2 hybrids obtained from these crosses segregation was not observed.

Thus, the beets with light green foliage isolated at Longmont belonged to the chlorina type and their light green foliage was caused by the action of the gene of the same locus as the gene ch_2.

In 1955 I studied also the recessive gene of the chlorina-type isolated in the inbred line SLC 1022 *mm* which originated from Kleinwanzleben's beets (Table 6).

Interaction between certain genes for chlorophyll deficiency. In the description of the virescens type of chlorophyll deficiency in beets, it was shown that the combination of two different homozygous genes (vi_1 and vi_2) produced non-viable homozygotes ($vi_1vi_1vi_2vi_2$) in the F_2 generation. At the same time the heterozygour F_1 plants ($Vi_1vi_1Vi_2vi_2$) were completely viable (Table 4). However, if the homozygous genes of the virescens type were combined with the homozygous genes causing another type of chlorophyll deficiency, for example, with the gene of chlorina type, then the plants carrying two homozygous genes were completely viable under greenhouse conditions. The F_1 hybrids between two homozygotes which carried the above-mentioned genes, were normal green and the F_2 progeny segregated for nine green and seven yellow-green or golden-green plants (Table 7).

Table 7.—Interaction Between Virescens and Chlorina Genes for Chlorophyll Deficiency in F_2 Generation.

Hybrids	Year	Seedlings		χ^2
		Green	Yellow	
vivi X *ch ch*				
Observed	1955	97	92	
Calculated (ratio 9:7)		106	93	1.8645

5% point of probability $\chi^2 = 3.84$
1% point of probability $\chi^2 = 6.64$

Table 7 also shows that it was possible to distinguish by the color of seedlings and mature leaves the plants of the vi_3vi_3 genotype from the *chch* genotype in these hybrids.

When the gene *vi* (of virescens type) was combined with the gene *Au*, segregation was more complicated. In F_1 green and yellow plants were observed. F_2 offspring could be obtained only from the yellow F_1 plants, because only these plants carried the gene *Au*. These yellow F_1 plants produced, after selfing, F_2 progeny which segregated in the ration: 3 green (1 *ViViauau* + 2 *Viviauau*) : 6 yellow (4 *ViviAuau* + 2 *ViViAuau*) : 3 golden yellow (2 *viviAuau* + 1 *viviauau*) : 4 albino (1 *ViViAuAu* + 2 *ViviAuAu* + 1 *viviAuAu*) seedlings. The three viable classes gave F_3 families which confirmed the correctness of the accepted classification.

The effect of environment on chlorophyll formation in different chlorophyll-deficient races. Cultivation of beets belonging to the main types of chlorophyll-deficiencies suchas Aurea (*Auau*), chlorina (*chch*), virescens (*vivi*), and albino (w_1w_1) in different environments showed that temperature and light influenced very much the formation of chlorophyll in these mutants.

Differences in the development of chlorophyll-deficient races were especially obvious when these races were cultivatd in the greenhouse or under field conditions. Different development in the same races was also observed in spring and fall plantings.

Brighter light and higher temperature usually increased the depressive action of the genes *Au*, *ch*, *vi*, and w_1 on the development of the beets. The influence of environment on the development of chlorophyll-deficient types could be illustrated by the following examples:

Lethal chlorophyll mutants—*AuAu*. The albino seedlings AuAu died under field conditions three days earlier than in the greenhouse.

Semi-lethal chlorophyll mutants *Auau*. These heterozygous yellow seedlings developed almost normally in the greenhouse. After 60-80 days of growth under greenhouse conditions they developed green leaves and produced a fair amount of seed. The stecklings of the same mutant (*Auau*) when planted in the field in spring developed chlorotic foliage and had considerably decreased seed production.

Virescens type—*vivi*. These homozygous beets developed golden seedlings. The plants grew in the greenhouse very slowly at the beginning, but later they accumulated more and more chlorophyll. In spite of this they developed under greenhouse conditions smaller roots than normal beets and produced less seed. When planted in the field, even in the fall, all homozygous *vivi* plants perished due to the loss of ability to accumulate chlorophyll.

The classification of many chlorophyll-deficient races becomes conditional because of the variation caused by the environment. The races which were denoted as "virescens" under greenhouse conditions, could be easily classified as "xantha" in field plantings. The races with yellow cotyledons which gradually turned green were denoted as virescens, because they were more viable than some other races with yellow seedlings which I observed

Table 8.—Interaction Between Virescens and Aurea Genes for Chlorophyll Deficiency in F_2 Generation.

Hyrids	Year	Seedlings				χ^2
		Green	Yellow	Gold	Albino	
Auau X vivi:						
Observed	1954	93	173	97	121	
Calculated (ratio 3:6:3:4)		91	181	91	121	1.164
Observed	1955	55	88	39	73	
Calculated (ratio 3:6:3:4)		48	95	48	64	4.4897

5% point of probability $\chi^2 = 7.82$
1% point of probability $\chi^2 = 11.34$

before and from which I could hardly obtain seed even in the greenhouse, although their heterozygotes were normal green. The differences in the development of chlorophyll-deficient mutants under the influence of environment which I am discussing in beets were also described for other crops; Akerman (2) in oats, Smith (42), and Holm (17) in barley.

The grade of dominance of the genes causing chlorophyll deficiencies also varied under different conditions. Homozygous and heterozygous beets of chlorina type were as viable in greenhouse as in the field. However, the homozygotes *chch* looked much lighter in field than in the greenhouse. The heterozygotes *Chch* did not differ in the greenhouse from the normal green plants. The gene *ch* was recessive under greenhouse conditions. Another kind of behavior was observed in the field. The seedlings heterozygous for the gene *ch* were normal green while the homozygous seedlings were light green. In the late summer the heterozygous plants turned lighter and could be distinguished from the normal green plants. At the time of harvest the heterozygous plants lost still more chlorophyll and it was difficult to distinguish them from the homozygous recessive plants *chch*.

In such a way the grade of dominance changed during the vegetative period, as can be seen from the data of segregation in such hybrids. (Table 9).

Table 9.—Segregation in F_2 Chlorina Hybrids (Field Observations in 1953).

Reading in:	No. of plants with color of leaves as follows:		
	Green	Light-green	Total
July	36	11	47
October	14	33	47

Intensity of green color of leaves in sugar beets. Sugar beet plants within commercial populations differ in quantity of chlorophyll in the leaves. The differences in the quantity of chlorophyll represents the main factor causing the variation of the intensity of green color of leaves in individual beets. Many investigations (27, 28, 29, 31) showed a high correlation between the quantity of chlorophyll determined by the spectrophotometer in the leaves and the intensity of their green color. Therefore, for the determination of the intensity of a green color of leaves, color standards may be used making possible the classification of large numbers of plants in a short time.

To determine the intensity of green color of leaves the color standard of E. F. Votchall was applied. This color standard contains 16 classes for the intensity of gree color, from light green to dark green. Each class is divided into four sub-classes, which do not differentiate in the quantity of chlorophyll but correspond to different shades of beet leaves. The color standard was graduated according to spectrophotometer readings and the readings of the color standards themselves showed the quantity of chlorophyll which the leaves contained (28, 31). The differences in the quantity of chlorophyll (chlorophyll $_a$) between classes of this standard equaled 0.009 to 0.01 mgr. per one square cm. of the leaf blade.

Lines of sugar beets differ very much in the quantity of chlorophyll (40). Sugar beet races rich and poor in chlorophyll with dark and light foliage were obtained after selection for the intensity of the green color of leaves. A. C. Okonenko (28) was the first to start breeding for quantity of chlorophyll. He showed that plants selected for intensity of green color and propagated in isolations produced offspring with striking differences in the intensity of green color of the foliage.

I studied the inheritance of intensity of green color by using sugar beet clones (38, 39, 41). Table 10 shows the characters of the original clones and of their F_1, F_2, and backcross hybrids. Reading of the intensity of green color was done several times for each plant individually. The data showed the following:

1. When light green clone 37 was crossed to the light green clone 161, the F_1 hybrids were almost as light green as their parents.

2. When dark green clone 61 was crossed to dark green clone 205, the F_1 hybrids were almost as dark green as the parents.

3. When light green clone 37 was crossed reciprocally to dark green clone 66, the F_1 offspring were intermediate in color in both cases.

4. In both reciprocal F_2 hybrids populations derived from crosses of light green clone 37 to dark green clone 66, the interpopulation variability was much higher than in the corresponding F_1 hybrids.

5. When F_1 hybrids (Cl. 37 x Cl. 66) were crossed back to the light green clone 37, the offspring appeared to be lighter than the F_1 generation and vice versa when the same F_1 hybrids were crossed back to the dark green parental clone 66. The offspring were darker than the F_1. In both cases the backcross hybrids were intermediate in cleaf color between the F_1 and recurrent parents.

Table 10.—Variation in the Intensity of Green Color of Leaves in Sugar Beet Clones and Their F_1, F_2, and Backcross Hybrids Determined According to Color Scale of Prof. E. Votchal.*

Generation	Designation of Parents and Hybrids	Number of Plants With the Grade of Green Color as Follows:														Number of Plants	Mean	Standard Deviation	Coeff. of Variability Percent
		3	4	5	6	7	8	9	10	11	12	13	14	15	16				
Clone	P-37 with light green leaves			7	18	6	3									34	6.147	0.86	14.0
Clone	P-161 with light green leaves		4	6	16	8										34	5.824	0.94	16.1
F_1	P-37 x 161			11	39	29	11									90	6.444	0.96	14.9
Clone	P-66 with dark leaves										4	5	12	7	3	31	14.000	1.15	8.2
Clone	P-205 with dark leaves									3	3	6	15	8		35	13.628	1.20	8.8
F_1	P-66 X 205								6	8	8	21	35	19		97	13.319	1.42	10.7
F_1	P-37 X P-66					4	19	30	26	16						95	9.186	1.10	11.9
F_1	P-66 X P-37					3	9	18	6	4	3					43	9.186	1.09	11.9
Backcross	P-37 X (P-37 X P-66)			15	21	28	24	26	12	13		2				141	7.887	1.85	23.6
Backcross	P-66 X (P-37 X P-66)					5	16	20	28	16	14	19	18	18		154	11.272	2.37	21.0
F_2	P-37 X P-66			10	16	13	24	28	21	18	12	11	8	9	5	175	9.731	2.87	29.5
F_2	P-66 X P-37			6	20	25	37	36	39	30	19	17	11	15	5	260	9.896	2.68	27.1

* Intensity of green color increases with the increase of number of scale.

6. F_1 and F_2 hybrids obtained from reciprocal crosses between light green clone 37 and dark green clone 66 could not be distinguished. This was an indication that the genetic differences responsible for the intensity of green color which were observed in the usual sugar beet populations were caused mainly by the nuclear genes, but not by the elements of cytoplasm. The backcross hybrids confirmed this conclusion.

7. The genetic analysis of the F_1 and F_2 hybrids as well as of the corresponding backcross hybrids showed that the intensity of green color in beets is a quantitative character which is caused by the action of polygenes. Therefore, the inheritance of the quantity of chlorophyll in sugar beet races must be studied on the basis of methods usually applied for the study of the quantitative characters (24, 47, 34). However, the analysis of variability as well as of segregation for different grades of intensity of the green color of leaves is beyond the limit of this paper and will be elucidated later.

Summary

Genetic analysis is given for the following chlorophyll deficiencies in beets.

Albino (gene w_1), Aurea (gene *Au*), lutescens (gene *lu*), virescens (3 genes—vi_1, vi_2, and vi_3), and chlorina (genes ch_1 and ch_2).

The pecularities of interaction between genes vi_1 and vi_2 as well as between genes vi_3 and ch_2 and *Au* are discussed.

The effect of environment on some indicated genes is shown.

Chimeric plants with variegated leaves consisting of mosaic white and green tissue sectors originated more often as a result of changes in the heritable substances of plasma than in the result of nuclear mutations.

A genetic study of different hybrids showed that the inherited differences in the quantity of chlorophyll which are peculiar to different plants within commercial varieties are determined by the nuclear inheritance, that is, by the action of polygenes. These differences in color of leaves and in quantity of chlorophyll are independent of cytoplasmic inheritance. Therefore, the heritable variability of the production of chlorophyll in beets is caused by the following factors:

a. Variability of heritable elements of plasm or cytogenes (origin of chimeric variegated plants).

b. Major chromo-genes which cause major changes in chlorophyll (the genes of chlorophyll deficiencies).

c. System of nuclear polygenes which cause the polymorphism chlorophyll quantity in ordinary beet populations.

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An Evaluation of Mechanical Thinning of Sugar Beets in California

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In recent years the practice of complete mechanical thinning of sugar beets has increased greatly in several sugar beet growing areas of the United States (5)[2] (6). Hand thinning is a tedious task, a major item of expense in the culture of the sugar beet crop and is the last remaining obstacle to complete mechanization. Any procedure which holds promise of eliminating some of this task deserves prompt consideration. As with any new practice, however, it is important that its use be carefully evaluated to be sure that its adoption will result in an improvement in production efficiency. For this purpose, several field trials were conducted from 1952 through 1955 to determine the effect of down-the-row type mechanical thinners on sugar beet production in California.

Eleven field trials were conducted. Individual plots in all trials consisted of four-row strips through the field or experimental area. Each treatment in each trial was replicated from 3 to 7 times. The eight trials conducted in commercial fields were harvested by machine, usually of the Marbeet type. Beets from each individual plot were loaded in a separate truck. Each truck load was handled at a sugar company loading station in the usual manner with the exception that 4 or 5 samples were taken from each instead of the usual one. The average of these samples was used for determining average plot sucrose and tare percentages.

The three trials at the Experiment Station at Davis, California, were harvested by hand. Plots were at least 150 feet in length and four rows wide. One-hundred and fifty, 180, and 60 feet of all four rows were harvested in 1953, 1954, and 1955 respectively. Four, 20-beet samples were taken from each plot for sugar and tare determinations. Beets less than two inches in diameter were discarded.

Thinning machines used were the Silver "GW" Beet Thinner or the machine manufactured by the Dixie Implement Manufacturing Company.

In all trials, beets were thinned mechanically according to the procedure outlined by the machine manufacturer. Thinning heads were selected to leave at least 137 beet containing inches per 100 feet of row.

Stand counts were made before and after thinning at two locations across the area selected for each trial. All four rows of each plot were counted for each measurement taken. Thus each plot was represented by at least eight determinations for each measurement.

Final stand determinations were made two to four weeks after thinning. An objective was to select a stand evaluation procedure that would reflect yield differences. Previous experiments had indicated that a four-inch spacing between single beets is about as close as can be tolerated without reducing yields appreciably (4). A four-inch space, therefore, was selected

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[2] Numbers in parentheses refer to literature cited.

as the criterion for determining single, double, and multiple plant hills. If two beets occurred within a four-inch space, it was a "double"; if three or more, a "multiple." Plants separated by four inches or more were "singles." These determinations were made in six of the trials.

To measure the effect of gaps between plants, a procedure outlined by the late G. W. Deming was followed (2). Each gap in excess of 16 inches was measured and the distance in excess of 16 inches considered as "row unoccupied." Such unoccupied spaces were totaled per 100 feet of row to develop the measure "percent row unoccupied."

Results and Discussion

Harvest results for all trials are given in Tables 2 and 3. Highly significant differences in root yield occurred in 8 of the 11 trials with hand thinned plots yielding from 0.7 to 6.5 tons per acre more than plots thinned entirely by machine. When long-handled hoes were used to trim machine thinned beets, root yields were usually increased compared to beets thinned completely by machine.

There was a significant difference in percent sugar in only one trial. This was a 0.5 percentage point increase in favor of machine thinned beets. Coefficients of variation for sugar percentage in the various trials were low, indicating that possible differences in sucrose percent could be measured with a high degree of precision. Failure to consistently measure differences indicates that mechanical thinning had very little effect on sugar percent.

Tare dirt, which includes small beets removed by screens at loading stations, was significantly higher for machine-thinned plots in two trials. Differences in tare dirt between the two thinning methods in terms of tons of waste material per acre was not great.

Laboratory tare percentage tended to be higher for machine-thinned beets in most of the trials and significantly higher in two. Differences in laboratory and beet-dump tare in favor of hand-thinned beets can account for some of the differences in root yield of clean beets. In most cases, however, the differences in laboratory and beet-dump tare are not great enough to explain the major portion of differences in clean root yields.

If a new practice contributes to farming efficiency, it should increase, or at least not decrease, net income. Under present economic conditions in California, a grower cannot afford a yield reduction of much more than one ton per acre by thinning mechanically as compared to hand thinning without reducing his net income from sugar beets. The economic effects of mechanical thinning have been reported elsewhere (3).

Table 4 gives detailed stand determinations for the six trials in which they were made. Root yields and the results of multiple correlation analyses are also given. It can be seen from these data that two stand determinations, four-inch spaces containing three or more plants and percent row unoccupied, quite consistently show close relationship to root yield. These two measurements reflect, to some degree at least, the primary reasons for poor stands: crowding of plants and unoccupied space. A count of single plants may correlate fairly well with root yields but may not necessarily reflect either of these important reasons for yield losses. Total hills per 100 feet is obviously a very poor measure of an adequate machine-thinned stand. By this

criterion, machine thinned stands in all but trial eleven in Table 4 would be considered excellent. Such counts, of course, do not reflect the very important consideration of hill distribution. When a beet containing hill is defined as one inch of row that contains one or more plants, total hills per 100 feet of row become an even more inadequate measure of stand. The employment of this latter definition of a beet hill in the blind use of mechanical thinners is, in our opinion, a principal reason for the poor results obtained with twice-over thinning. Excellent pre-thinning stands existed in the trials reported here. Thinning heads were selected to leave at least 137 beet-containing inches per 100 feet of row. In most cases row unoccupied was a principal cause of reduced yield. Had knives been selected to leave the commonly desired 100 hills per 100 feet of row, even greater yield reductions might have occurred. Table 5 shows, for two trials, the increase in row unoccupied with successive passes of the thinner.

While the stand evaluation procedure adopted for these trials is not perfect by any means, it appears to be a step in the right direction. There is a need for more work to develop a fairly simple system that can be easily used in practical field work. In particular, different space intervals should be considered, in addition to 16 inches, for determining row unoccupied. Other methods of determining multiples might also be investigated.

Summary and Conclusions

Eleven field trials were conducted to evaluate complete machine thinning in comparison with the conventional hand thinning method. An attempt was made to develop a procedure for stand evaluation that would more accurately reflect differences in root yield. Results indicated that:

1. Complete mechanical thinning reduced root yield in every trial from 0.7 to 6:5 tons per acre. Trimming mechanically thinned beets with long-handled hoes increased yields in most cases when compared to complete mechanical thinning, but in no instance equalled the yield of hand thinned beets.

2. Sucrose percentage was not affected by mechanical thinning to an important degree.

3. Mechanical thinning tended to increase the amount of tare dirt and small beets screened out at loading stations. This increase was not great.

4. Laboratory tare percentage tended to increase as a result of mechanical thinning.

5. Excellent root yields were produced by mechanically thinned beets. Under current economic conditions, however, a loss of much more than one ton per acre cannot be tolerated without reducing net income.

6. Differences in root yields were correlated quite well with stand measurements reflecting four-inch blocks containing three or more beets and percent row unoccupied.

Acknowledgment

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Table 1.—Stand Before Thinning, Thinning Heads Used, Number of Replications, and Harvest Method. Mechanical Thinning Field Trials.

	Trial Number, Location (County or Nearest Town) and Year Conducted										
	No. 1 Butte 1952	No. 2 Butte 1953	No. 3 Butte 1954	No. 4 Butte 1954	No. 5 Butte 1955	No. 6 King City 1953	No. 7 Davis 1953	No. 8 Davis 1954	No. 9 Davis 1955	No. 10 Yolo 1955	No. 11 San Benito 1954
Beet containing inches per 100 inches before thinning	31	35	33	—[1]	38	48	33	37	35	32	40
Thinning heads used— first pass	8x1	8x1½	16x⅞	—[1]	8x1¾	10—2	10—1½	10—2	10—2	10—2	8x1¾
second pass	16x¾	none	none	—[1]	16x¾	20L½	20L½	8L2	20L½	20L½	16x¾
Number of replications	3[2]	3	3	3	6	6	6	5	7	6	6
Harvest method[3]	M	M	M	M	M	M	H	H	H	M	M

[1] Information not available

[2] Only 2 replications of machine thinned plots

[3] M is machine harvest, H is hand harvest

Table 2.—Effect of Thinning Method on Sugar Beet Root Production and Sucrose Concentration.

Thinning Method	Trial Number											Average All Trials
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	
	Tons, Clean Beets Per Acre											
Short hoes	15.5	17.8	18.5	16.8	29.2	32.0	34.0	25.3	30.4	27.1	29.3	25.1
Machine[1]	14.7	16.5	17.8	15.3	25.8	28.6	27.5	22.5	24.1	24.7	22.8	21.8
Machine plus long hoes	15.0	16.9	17.8	15.9	—	—	30.9	24.2	26.8	—	—	
LSD, 19:1[2]	ns.[2]	ns.	ns.	1.7	0.9	1.1	2.3	2.1	2.4	1.6	1.7	
C.V[2]	3.2	4.4	5.0	5.5	3.5	2.7	6.0	6.6	6.6	4.1	4.9	
	Percent Sucrose											
Short hoes	17.6	13.9	14.9	16.1	16.2	16.0	13.7	13.1	14.0	13.9	15.4	15.0
Machine	17.3	14.1	14.7	16.4	16.7	15.9	13.8	13.5	14.0	14.0	15.5	15.1
Machine plus long hoes	17.3	13.9	15.8	16.2	—	—	13.9	13.8	14.0	—	—	
LSD, 19:1	ns.	ns.	ns.	ns.	0.2	ns.	ns.	ns.	ns.	ns.	ns.	
C.V.	3.0	1.4	2.9	2.2	1.0	1.0	2.2	6.7	2.7	3.1	2.0	

[1] Machine refers to Silver or Dixie down-the-row type thinner.

[2] LSD indicates least significant difference. NS means not significant. CV refers to coefficient of variation.

Table 3.—Effect of Thinning Method on Beet Dump and Laboratory Tare.

Thinning Method	Trial Number											Average All Trials
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	
	Tons Tare Dirt Per Acre Removed at Beet Dump											
Short hoes	—	0.81	0.99	5.7	0.98	1.14	—	—	—	1.1	5.8	2.36
Machine	—	1.28	0.97	5.9	1.08	1.40	—	—	—	1.2	4.3	2.30
Machine plus long hoes	—	0.87	0.94	4.6	—	—	—	—	—	—	—	—
LSD, 19:1	—	0.16	ns.	ns.	ns.	0.08	—	—	—	ns.	ns.	
	Laboratory Tare Percentage											
Short hoes	11.1	9.6	6.6	14.1	6.1	5.8	—	—	—	10.1	15.5	9.86
Machine	12.7	12.2	7.9	14.2	6.7	8.5	—	—	—	11.9	14.1	11.02
Machine plus long hoes	12.4	10.1	7.6	12.2	—	—	—	—	—	—	—	—
LSD, 19:1	ns.	1.8	ns.	ns.	ns.	1.5	—	—	—	ns.	ns.	

Table 4.—Effect of Thinning Method on Stand and Root Yield.

Thinning Method	Stand After Thinning 4-inch Beet Containing Blocks Per 100 Feet				Percent Row Unoccupied	Tons Roots Per Acre
	Singles	Doubles	Multiples	Total		
Trial No. 8, Davis, 1954						
Short hoes	102	39	10	151	0.5	25.3
Long hoes	68	29	23	120	1.8	24.7
Machine	40	29	48	117	7.3	22.5
Machine plus long hoes	48	26	20	94	8.7	24.2
Machine, tines first	45	29	44	112	7.5	21.8
Significant difference, 19:1						2.1
Partial correlation coefficients[1]			—0.314		—0.491*	
Regression equation[1]		Y = 25.270 — 0.129 Xg — 0.026 Xm				
Trial No. 9A, Davis, 1955						
Short Hoes	121	26	4	151	1.6	31.0
Machine	43	35	63	141	3.5	24.1
Significant difference, 19:1						2.6
Partial correlation coefficients			—0.870***		—0.569*	
Regression equation		Y = 32.362 — 0.567 Xg — 0.10 Xm				
Trial No. 9B, Davis, 1955						
Short hoes	119	28	4	151	0.4	29.7
Machine plus long hoes	50	33	26	109	4.7	26.8
Significant difference, 19:1						2.2
Partial correlation coefficients			—0.102		—0.499	
Regression equation		Y = 29.97 — 0.559 Xg — 0.024 Xm				
Trial No. 11, San Benito, 1954						
Short hoes	139	6	0.7	145.7	2.7	29.3
Machine	46	22	15	83	25.0	22.8
Blocker plus short hoes	89	11	2	109	7.8	27.1
Significant difference, 19:1						1.7
Partial correlation coefficients			—0.489*		—0.822***	
Regression equation		Y = 29.402 — 0.199 Xg — 0.106 Xm				
Trial No. 10, Yolo, 1955						
Short hoes	83	32	9	124	3.5	27.1
Machine	40	27	40	107	12.7	24.7
Significant difference, 19:1						1.6
Partial correlation coefficients			—0.668*		—0.231	
Regression equation		Y = 27.86 — 0.074 Xg — 0.056 Xm				

Table 4 continued on next page.

Table 4, continued.

			Trial No. 5, Butte, 1955			
Short hoes	137	82	7	226	0.4	29.2
Machine	56	51	33	140	7.9	25.8
Significant difference, 19:1						0.9
Partial correlation coefficients			—0.655*		—0.565	
Regression equation			Y = 29.695 — 0. 181 Xg — 0.073 Xm			

[1] Partial correlation coefficients derived from multiple correlation of tons per acre on multiples (Xm) and percent row unoccupied (Xg).

*,*** Significant at 5 percent and 0.1 percent levels respectively.

Table 5.—Effect of Successive Passes of Down-the-Row Thinning Machines on Unoccupied Row Space.

Thinning Operation	Percent Row Unoccupied	
	Trial No. 5[1]	Trial No .10[2]
Before thinning	0.16	0.75
After 1st pass	1.2	4.2
After 2nd pass	7.9	12.7
Hand thinning	0.4	3.5

[1] Pre-thinning count = 37.9 beet containing inches per 100 inches. Heads used: 8 x 1¾ and 16 x ¾ to leave 146 beet containing inches per 100 feet.

[2]Pre-thinning count = 31.9. Heads used: 10-2 and 20L½ to leave 140 beet containing inches per 100 feet.

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A Comparison of the Dirt Screen Efficiency of Beet Receiving Equipment in Use in the Alberta, Canada, Area Served by Canadian Sugar Factories Limited

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Area Data

The region served by Canadian Sugar Factories Limited lies between 49° and 50° North Latitude and 112 and 113 Meridian West Longitude and centers on the city of Lethbridge in the Province of Alberta, Canada. The first factory was erected at Raymond in 1925 and has operated continuously since. Factories were subsequently erected at Picture Butte in 1936 and Taber in 1950. These three plants now have a combined daily slicing capacity of 6000 tons of beets.

The ten-year average yield from the 38,500 acres of beets harvested annually is 12 tons per acre. Beets in Alberta are normally planted April 20 to May 20 and harvested in October. The average number of frost free days is 140.

Purpose

Preliminary tests were made during the fall of 1955 to study the respective efficiency of dirt screens utilized by company beet-receiving equipment comprising 27 units in all, located at its three factory and thirteen tributary railway points.

Equipment and Screens

All dirt screens in the area were originally of the rotating squirrel-cage design. Subsequent changes introduced the potato chain in 1930 and 1946; steel Rienks-type screens in 1934; the first rubber Rienks-type screens going into service in 1951.

The equipment used in this study was located at the three factory and four of the country points and consisted of twelve 36-inch Silver Engineering Works pilers—half with rubber and half with steel Rienks screens operated at various speeds; two Ogden Iron Works stations with rubber Rienks screens; one loading station with potato chain-type screen; one station with squirrel-cage rotating-type screen. Specification details and operating data covering the equipment tested are shown in column A Table 1.

All 36-inch Silver piler Rienks screen, both rubber and steel elements, are 12 inches in outside diameter and have clearances of 1⅝-inch and 1⅜-inch respectively between kickers. However, due to greater hub and element widths on the rubber screens there is less space to permit dirt, clods, and trash to fall through onto the dirt belt. This was calculated by Johnson (1)[2] to be 20 percent less on rubber screens having 60-inch by 8-inch roll specifications. The Ogden Iron Works screens utilize 14-inch O.D. kickers

[1]General Agricultural Superintendent, Raymond, Alberta, Canada, and Factory Agricultural Superintendent, Picture Butte, Alberta, Canada, respectively, Canadian Sugar Factories Limited.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Comparison of Results Grouped According to Type and Speed Dirt Screen.

*Screen Type Size and Speed	Net Tons Beets	Percent Tare	Ave. Wt. Beets	Lbs. Tare Ret'd P/Ton Beets	Lbs. Beets Ret'd P/Ton Beets	Dirt Removal Efficiency Rating	Beet Loss Efficiency Rating
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Steel Rienks (Silver)							
537 FPM x 8R x 60" x 1-3/8" x 12"	839	4.2	1.50	171	.18	85	3
427 FPM x 8R x 60" x 1-3/8" x 12"	303	4.1	1.55	197	.10	100	2
Rubber Rienks (Silver)							
537 FPM x 8R x 60" x 1-3/8" x 12"	654	4.0	1.72	137	.33	71	4
427 FPM x 8R x 60" x 1-3/8" x 12"	504	4.2	1.47	184	.56	91	5
361 FPM x 10R x 71" x 1-3/8" x 12"	390	9.1	1.26	315	nil	72	1
Rubber Rienks (Ogden)							
452 FPM x 11R x 55" x 2" x 14"	533	4.3	1.42	191	1.19	92	7
452 FPM x 14R x 72" x 2" x 14"	353	4.9	1.49	245	3.27	104	8
Potato Chain							
198 FPM x 140" x 38" x 1-3/4"	262	5.4	1.42	184	.85	71	6
Squirrel Cage							
348 FPM x 110" x 42" x 1¼	149	7.1	1.51	190	nil	56	1

* Screen specifications—537 FPM x 8R x 60" x 1-3/8" x 12" refers to screen with peripheral or surface speed of 537 feet per minute x 8 screen rolls 60 inches in length having kicker wheels 1-3/8" apart at outer circumference and having outside diameter of 12 inches.

and 2-inch element interspaces. The squirrel cage bars have 1¼-inch spacing while the potato chain screen under study has inter-bar space of 1⅜-inches.

Tons of beets passing over the screens under maximum load conditions were determined to be 3.68 tons per minute at 415 FPM increasing to 4.66 tons per minute or 26 percent greater at 530 FPM where the entire piler had been speeded up to increase receiving capacity, by enlarging the size of the motor drive pulley from 7-inch to 9-inch O.D. Load tests, unfortunately, were not made on pilers having been speeded up through increase of motor drive while the screen speed had been correspondingly slowed with compensating screen-drive sprocket changes. The potato chain was found to be passing 1.75 tons per minute, about one-half the volume of the lower speed Rienks screen.

For the purpose of discussion and analysis Rienks-type screen speed ranges have been grouped at four speeds:

[3]169 RPM to 173 RPM = Ave. 171 RPM = peripheral speed 537 FPM
[3]132 RPM to 140 RPM = Ave. 136 RPM = peripheral speed 427 FPM
[4]123 RPM = peripheral speed 452 FPM
[3]115 RPM = peripheral speed 361 FPM

Method

A total of 26 growers delivering approximately 5,000 tons of beets during the test period co-operated in the project. Five growers, selected

[3] 12 inches O.D. Rienks kicker wheels.
[4] 14 inches O.D. Rienks kicker wheels.

at each factory point, were instructed to distribute their daily deliveries to all the receiving units in service at their respective stations for the 6-day period, October 13 to 20, 1955, making sure some beets were delivered to each. A minimum of two to three growers at each country point were similarly selected and, where practical, made deliveries to a station other than their own each day.

Each load as delivered was weighed in and out including tare dirt and empty truck over company receiving scales. Return dirt was removed from the truck and the truck re-weighed to obtain accurate weight of dirt returned through dirt screen. Weight of all beets having a diameter of two inches or greater returned with dirt from the piler was determined at the time the dirt was unloaded. All loads were tared for dirt and top growth at the respective piler or station when they were received. The data obtained were analyzed by grower and grouped according to unit over which the beets were received. This information subsequently summarized appears in Table 1 and Table 2.

Beets received during the test period were considered in excellent condition for storage and processing, being generally crisp and moist following light rains the first 10 days of October. No further moisture fell while the tests were being conducted. Average dirt tare over the three factory area was 5.25 percent for the test period.

Discussion

The efficiency measure of any screening equipment is the actual dirt and trash removed from delivered beets in relation to total amount in the loads, while at the same time conserving the maximum quantity of processable beets.

Using these two factors, dirt removed and high beet retention as yardsticks, the conclusions suggested are set out in columns G and H Table 1, where results are analyzed according to type and speed of screen.

It was felt that the results for all screens where dirt tares fell into the 4 percent to 5 percent tare range were directly comparable on the basis of pounds of dirt returned to truck per ton of clean beets received. At the higher tare levels of 9.1 percent and 7.1 percent obtaining over the 361 FPM rubber Rienks screen and the squirrel cage respectively, it was assumed they should have returned dirt to the truck in direct proportion to the higher tare secured.

The standard 60 inch by 8 inch roll screen returning the greatest quantity of dirt to truck per ton of beets (column E) in relation to percent tare was the steel screen operating at a speed of 427 FPM which actually removed 70.6 percent of total dirt. For convenience in comparison this screen was given an efficiency rating of 100. The other screens were then rated accordingly on the assumption that they should remove dirt in proportion to percent tare or amount of dirt going over the screen and into storage piles. The results are shown in Table 1.

Note that the greatest combined efficiency was secured on 60 inch by 8 inch roll steel Rienks screen at 427 FPM but ranked second in dirt removal and second in beet conservation. While the 72 inch by 14 inch roll rubber-Rienks screen removed 4 percent more dirt, not surprising in view of its much greater area, it was considerably more wasteful in terms of beets

returned—3.27 pounds per ton of beets delivered. The 60 inch by 8 inch roll Rienks-type steel screen eliminated more dirt at 537 FPM when compared to the larger 72 inch by 10 inch roll rubber screen operating at a lower speed of 361 FPM in spite of the larger area of the latter. The rubber Rienks-type screen at 427 FPM showed superiority over the rotating squirrel cage where the 7.1 percent dirt tare suggests that a relatively large amount of dirt is passing over the screen to storage.

The high loss of beet tissue through the two inch spacing on two of the rubber screens suggests that this opening should be reduced in size. It will be noted in two instances that fewer beets are removed with the dirt at the lower speeds for equivalent wheel spacings. If it is accepted that the majority of these are removed by the reverse rolls, then probably some study should be made on the effect of slowing the reverse rolls down in relation to the forward rolls.

Table 2.—Comparison of Rubber vs. Steel Rienks Dirt Screens at Four Alberta Locations—All Speeds and All Deliveries Grouped.

	RUBBER SCREEN					STEEL SCREEN					
Location	Net Tons Beets	Percent Tare	Ave. Wt. Beets	Lbs. Tare Ret'd P/T.B.	Lbs. Beets Ret'd P/T.B.	Net Tons Beets	Percent Tare	Ave. Wt. Beets	Lbs. Tare Ret'd P/T.B.	Lbs. Beets Ret'd P/T.B.	Rubber Effic. Steel Based @ 100
Raymond	335	4.5	1.40	206	.62	690	4.1	1.45	188	.10	equal
Coaldale	140	6.6	1.63	223	.70	200	6.6	1.65	269	.40	83
Picture Butte	390	9.0	1.27	315	nil	198	8.3	1.36	320	nil	91
Taber	823	4.0	1.68	142	.36	557	4.0	1.65	156	.24	91
Av. mean	422	6.0	1.49	221	.42	411	5.7	1.53	233	.19	

Table 2 summarizes rubber vs. Steel Rienks-type screens at locations where both were in use. The results lead to the general observation that, at three of the four locations, the steel screens provided greater efficiency in the removal and return of dirt to the grower, while at the same time provided a maximum saving of beet tissue.

Several observations based on operating experience with the various types of screens would appear pertinent to this study.

Soil Type and Moisture Content at Delivery Time

Experience in Alberta has brought about the virtual abandonment of the squirrel cage type screen because of its tendency to clog solidly with mud and leaves on the outer circumference when beets are delivered in a reasonably moist condition. As a result, excessive quantities of dirt pass with the beets into factory flumes and wet hoppers resulting in high receiving and freight costs and factory processing delays.

Although the potato chain does not plug up and slow deliveries, it likewise has a tendency to pass excessive dirt over with beets.

The Rienks type screens have become standard in this area because of their higher capacity and greater efficiency under extreme conditions of load and stress.

Effect of Soil Types on Rienks Type Screen Wear and Replacement Costs

Under Alberta conditions, the steel Rienks kickers have an average life expectancy of approximately 200,000 tons of beets before some replacement becomes necessary. There is little difference for the various soil types.

This is in sharp contrast to experience with rubber. For example, at the Picture Butte factory where fine silt and clay loam soils predominate, replacement of some rubber kickers (particularly where the beets are discharged onto the screen) will be necessary after handling 150,000 tons; while at the Taber factory (where sharp and highly abrasive sandy soil types predominate), replacement of some screen sections have been necessary at the 50,000 to 75,000 ton level.

Rocks and Excess Mud

Rubber screens have proven to be superior to steel, particularly from the standpoint of reducing receiving time delays because of screen stoppage due to rocks in areas where rocks are a factor. At the same or higher speed, rubber screens are considered to require less cleaning and result in less delay under muddy conditions. However, while rubber may continue to rotate at the higher speeds under conditions of extreme mud, the importance of keeping hubs clean to prevent excessive kicker wear must be strongly emphasized.

Summary of Conclusions

The results of this study and Alberta operating experience seem to warrant the following conclusions.

1. Steel Rienks-type screens were more efficient both as to dirt removed and beet tissue conserved than rubber Rienks-type screens of the same size and rotation speed for all locations included in the tests.

2. Speed of screen rotation and travel appear to have a direct bearing on the efficiency of both rubber and steel type screens. The most efficient speed would appear to lie in the 420 to 440 FPM range for 12 inch O.D. screen elements. The volume of beets and quantity of dirt they carry has a bearing on this and perhaps justifies further study.

3. The Rienks-type screens, both steel and rubber, provided greater efficiency than the potato chain and rotating bar types.

Under Alberta conditions and at average crop yields of 12 tons per acre, the 1⅝ inch provided between individual kicker elements on rubber screens would appear to be optimum if maximum beet tissue is to be salvaged, this perhaps suggests the need for intensified engineering studies to more closely approximate the steel screen relations in this respect, as well as increasing screening area as suggested by Johnson (1).

5. Rubber screens cause less receiving delays and interruptions compared to steel, under conditions of rocks and extreme mud.

6. Wear and maintenance of rubber Rienks-type screens are increased over steel in receiving beets from moist abrasive-type soils.

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Respiratory Losses from Sugar Beets Soon After Harvest

MYRON STOUT[1]

Most of the published data concerning the respiratory loss of sugar from stored sugar beets have been concerned with the post-harvest losses that occur over a relatively long period of time. The magnitude of losses over extended periods of time can be determined by chemical analysis of carefully selected samples before and after the storage period. Small losses sustained by beets over a short period of time require very careful selection, handling, and analysis of a large number of samples for statistically significant results.

Direct measurements of respiration rates are far more accurate than chemical analysis of selected samples before and following experimental storage because fewer factors affect respiration rate than affect chemical composition. One set of data involving eight replications of analytical samples and only four replications of respiration rate samples showed errors only 1/13 as great in the respiration rate measurements as that determined by chemical analysis of the same matched samples before and after storage for 38 days at 72° F. The losses calculated from respiration data required differences of only 0.07 percent sugar for significance while the losses, based on analytical data, required differences of 0.92 percent sugar for significance at the 5 percent point.

Many beets are stored for only a few hours or days before processing. Since these beets undergo losses, it seems pertinent to examine the rate of loss in relation to the length of time they are stored following harvest.

Most tissues exhibit a rapid rise in respiration rate following injury (2) (1)[2]. Some of this rapid increase in CO_2 output is undoubtedly due to the escape of gas that has accumulated in the intercellular spaces of the tissues. This is especially true of massive tissues such as the sugar beet, or potato tubers. The removal of the periderm probably also makes the tissue more permeable to oxygen until suberization reduces the permeability. Frequently, an injury that fails to rupture the periderm fails to produce the usual rise in respiration rate.

Two principal factors have been responsible to a large degree in minimizing early post-harvest data. It usually takes one or two days to get the beets harvested, washed, uniformly topped, and the matched beet samples ready for all of the large drums. They must then be placed and sealed in the drums and the system checked for leaks and time allowed for the beets to reach thermal equilibrium at controlled temperature. The oxygen concentration inside the drums is then checked and adjusted before the start of the first 24-hour measurements. The technique used (4) is also subject to variations due to changes in barometric pressure. Apparently changes in barometric pressure modify the rate of apparent oxygen consumption in a manner not entirely consistent with Boyles' law. It has, therefore,

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[1] Physiologist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

been the practice to average the respiration rates of several drums over 10-day periods and report these averages, which are more consistent values. High initial respiration rates are always observed. By averaging the daily values over several separate tests, one can reduce the fluctuations caused by changes in pressure and obtain fairly consistent average daily changes in the respiration rates.

Average daily respiration losses of sugar, calculated in pounds per ton of beets per day, were determined for six separate tests involving 16 drums of beets containing 88 pounds each. Each value, therefore, represents the average daily measurements on a total of 8,448 pounds of beets. The data in Figure 1 show that there were still some variations in the average barometric pressure during the first twenty-five days after the beets were harvested. The average changes from the third to the seventh day were small, however, and the changes in the respiration rate were apparently nearly linear between these points. It is very apparent that the sugar losses during the first few days are much higher than the basic rate of loss usually associated with previously reported studies. By extrapolating the curve to the time of harvest, it seems probable that the average losses during the first day after harvest occur at a rate more than twice as high as those usually considered by the writer as representative of the general storage period. It should be mentioned that in the absence of appreciable growth of fungi in the drums, there is a slightly progressive decrease in oxygen consumption

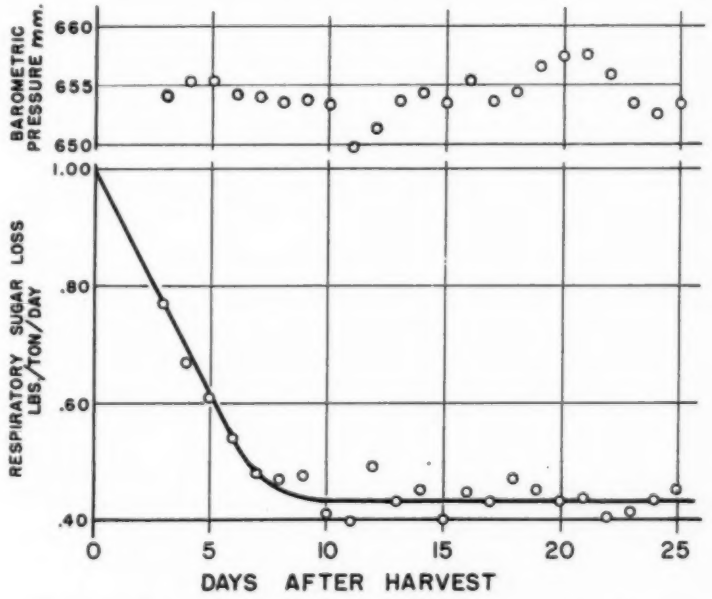

Figure 1.—Rate of respiratory loss of sugar from sugar beets in relation to time after harvest, tests conducted at 70° F.

until the end of the test (usually 40-50 days at 70° F.). An increase in oxygen consumption is commonly used by the writer to indicate the progress of spoilage, and the tests have been discontinued after these observations have indicated definite differential progress of spoilage between different treatments or varieties being studied.

Because of the much higher degree of precision possible in respiration rate measurements and the very small analytical differences involved in some short-period storage experiments it may be profitable to recalculate the losses from time-temperature data by applying respiratory loss observations. Orleans and Cotton (3) reported studies of storage losses at the Carlton plant of the Holly Sugar Corporation near Brawley, California, in 1949 and 1950. Temperature differences between the ventilated and check bins were fairly large after only a few hours. If we assume that the initial respiratory loss of freshly harvested beets at 70° F. is 1.00 pound of sugar per ton per day (see Figure 1) and that this loss is doubled for each 15° F. rise in temperature, then the initial loss of freshly harvested beets at any given temperature (T° F.) can be calculated by first converting the losses in Figure 1 at 70° F. to the losses at 40° F. by dividing by four and calculating the losses at any given temperature above 40° F. by the formula:

Loss (lbs. sugar per 1000 tons per hour

or

$$\text{Loss (lbs. sugar per 1000 tons per hour} = 10.42\ (10^{.02007\ (T-40)})$$

A graph showing the pounds sugar loss per hour per 1,000 tons of beets, calculated from temperature data of ventilated and unventilated beets by use of the above formula, is more convenient in estimating losses for short periods of retention in bins such as those reported by Orleans and Cotton. The savings in sugar, due to the use of forced ventilation on 225,000 tons of beets (3750 tons per day x 60 days) for the temperature differences reported for 1949 and 1950, would be as indicated in the following table:

Table 1.—Calculated Savings by Ventilating Sugar Beets for Short Periods of Storage Based on Temperatures of Ventilated and Check Bins at Carlton, California, in 1949-1950 (3) and Assuming a Total of 225,000 Tons of Beets Processed.

Average Retention Time in Bins	Sugar Saved Based on:	
	1949 Data	1950 Data
Hours	Pounds	Pounds
4	17,460	6,187
6	31,365	11,880
8	47,205	19,102
12	82,125	36,990
15	110,002	51,830
18	147,000	68,000

In addition to the respiratory sugar losses on which the data in Table 1 are based, Cotton and Orleans reported perceptible differences in purity loss during short periods of storage. The smaller loss of purity of the ventilated beets would also improve the extractability of the sugar present in these beets.

It is also possible to calculate from weather data at a given location the cooling of beets that could be expected by forced ventilation. Previous studies (5) have shown that the ambient air rapidly absorbs heat and increases in humidity in passing through a column of beets. Actual measurements of the cooling effected closely approximated the total calculated values obtained by heat transfer and evaporative cooling. Open piles might be further cooled by winds and increased draft through the sides of the piles induced by blowing air up through the piled beets.

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The Effect of Various Preceding Crops on Sugar Beets

S. Dubetz, G. C. Russell and K. W. Hill[1]

Introduction

Sugar beets occupy a large acreage in southern Alberta as compared with other irrigated cash crops. This crop receives special consideration in rotation planning because of its extent and high return per acre. Most sugar beet rotations are planned to provide the maximum production of the primary crop. The beneficial effects of barnyard manure, commercial fertilizer, timely irrigation, and legumes also receive consideration in deciding upon cropping practices (1, 4, 8)[2].

The sequence of cropping also has a marked effect on the yield of certain crops (5, 6, 7) and, therefore, is an important phase of rotation planning. In southern Alberta information was needed on the effect of crop sequence on the yield of sugar beets, irrespective of other rotational factors. An experiment was set out at the Lethbridge Experimental Farm in 1947 to study the effects on the following crop of some of the important crops grown under irrigation in southern Alberta. The results of this experiment are presented in this paper.

Procedure

In 1947 seven crops—canning peas, canning corn, potatoes, barley, soft spring wheat, sugar beets, and field beans—were grown in adjacent strips at four locations at the Lethbridge Experimental Farm. The crop varieties recommended for southern Alberta were used throughout the test. In 1948 these crops were grown transversely across the preceding strips and a summer-fallow strip, allowing each crop to be grown after itself, after fallow, and after the other six crops. The following year, the crops were grown crosswise to the 1948 plots, thus providing two years of sequence crops, and completing one cycle. All of the plots were seeded to oats in 1950, after which the experiment was repeated until two sequence cycles were completed.

To obtain maximum crop yields and yet maintain relatively uniform fertility, ammonium phosphate (11-48-0) fertilizer, at the rate of 100 pounds per acre, was applied each spring over the whole area of each location prior to seeding. No further fertilizer applications were made.

The size of each plot was 19 feet by 40 feet, and appropriate samples of each crop were harvested. In the calculation of the data for the analysis of variance, the locations were treated as replicates. All of the crops were irrigated with a perforated-pipe sprinkler system.

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[1] Agronomist and Head of Field Husbandry Section, Experimental Farm, Canada Department of Agriculture, Lethbridge, and Senior Agronomist, Central Experimental Farm, Canada Department of Agriculture, Ottawa, respectively.

[2] Numbers in parentheses refer to literature cited.

Results and Discussion

The yields of sugar beets for the four sequence years (1948, 1949, 1952, and 1953) following the different preceding crops appear in Table 1. Comparable results of the percentage sucrose of sugar beets are shown in Table 2. In Figure 1, the yields of each crop, excepting sugar beets, following the various preceding crops are depicted graphically. The gross returns per acre per year following each preceding crop, as calculated from the four-year average annual returns of the seven succeeding crops, are depicted graphically in Figure 2.

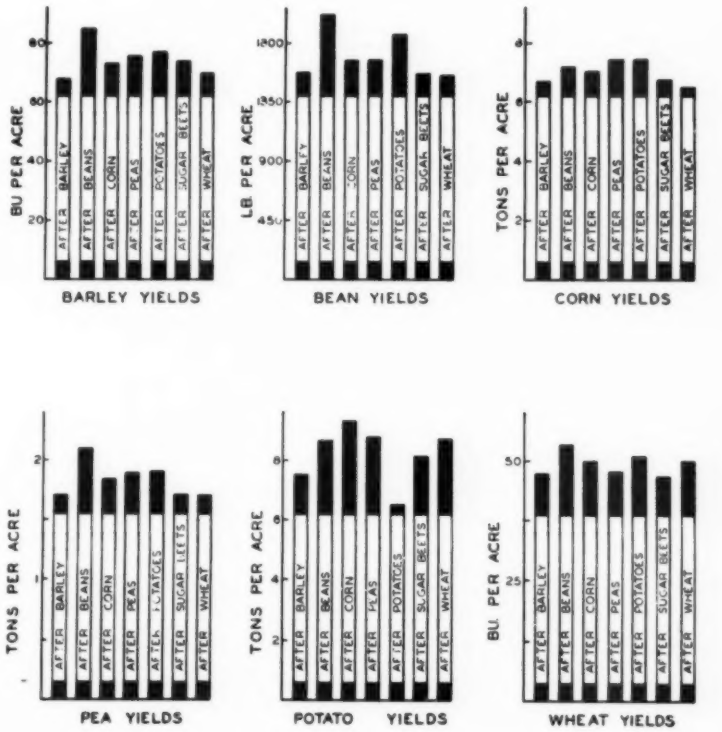

Figure 1.—Four-year (1948-49, 1952-53) average yields of each crop, excepting sugar beets, following the various preceding crops in a crop sequence test, Lethbridge, Alberta.

During three of the four sequence years (Table 1) the yields of sugar beets were highest after beans. In 1948 and in 1952 the yields of beets after beans were higher by more than one ton than the yields following any of the other six crops. Analysis of the four-year data revealed that the yields of sugar beets were significantly higher following beans than the

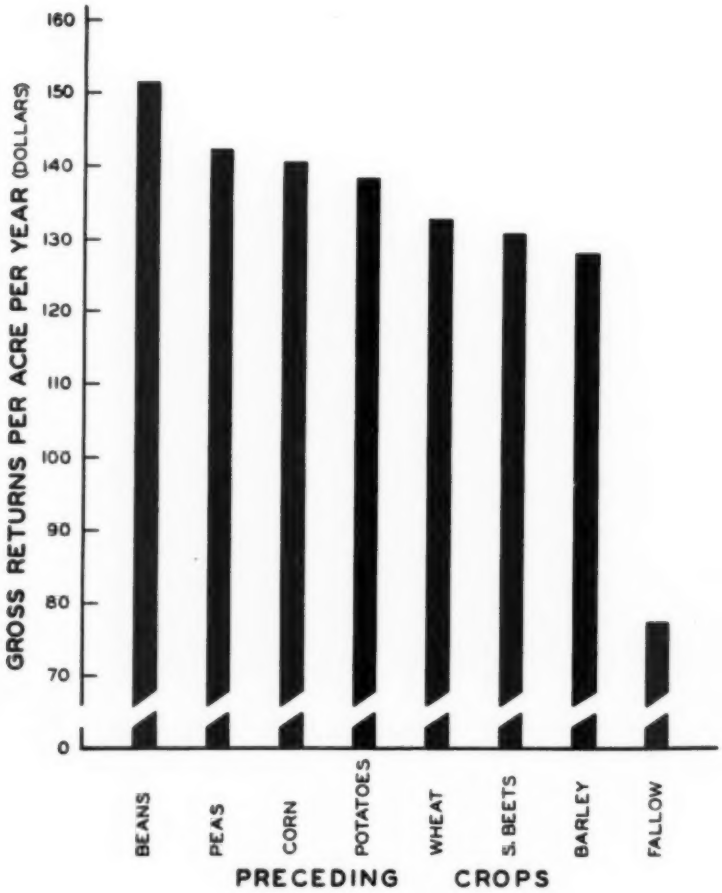

Figure 2.—Gross returns per acre per year following each preceding crop as calculated from the four-year average annual returns of the seven succeeding crops in a crop sequence test, Lethbridge, Alberta.

Table 1.—Yields of Sugar Beets for Four Sequence Years (1948, 1949, 1952, 1953) Following Different Preceding Crops and Summer-fallow in a Crop Sequence Test, Lethbridge, Alberta.

Year	Barley	Beans	Corn	Peas	Potatoes	Sugar Beets	Wheat	L.S.D.	Fallow
1948	11.02	14.18	11.57	11.91	12.76	11.72	10.52		13.13
1949	8.97	10.68	10.29	9.61	10.82	9.01	9.00		—
1952	15.18	18.56	14.80	17.49	17.54	14.08	15.97		19.10
1953	7.46	8.45	9.82	10.04	9.20	7.87	8.42		—
Mean	10.66	12.97	11.62	12.26	12.58	10.67	10.98	1.32	—

Table 2.—Percentages of Sucrose of Sugar Beets for Four Sequence Years (1948, 1949, 1952, 1953) Following Different Preceding Crops and Summer-fallow in a Crop Sequence Test, Lethbridge, Alberta.

Year	Barley	Beans	Corn	Peas	Potatoes	Sugar Beets	Wheat	Fallow
1948	16.2	15.5	15.7	16.0	15.9	16.0	15.2	15.7
1949	14.4	13.2	13.7	13.2	13.4	14.4	14.2	—
1952	16.8	16.2	16.0	16.3	16.8	16.0	16.3	16.4
1953	16.8	16.6	16.2	16.2	16.4	17.0	17.0	—
Mean	16.0	15.4	15.4	15.4	15.6	15.8	15.7	—

yields obtained following sugar beets, corn, wheat, and barley. Significant yield increases of barley, beans, and peas also were obtained after beans. Hence, on the basis of yields of succeeding crops, field beans were the outstanding preceding crop in the test.

The beneficial effect of beans as a preceding crop possibly is due to the additional nitrogen made available to the subsequent crops by this annual legume. This is in agreement with the findings of Guttay and Cook (3), who reported that additional nitrogen was not so beneficial in a sequence in which sugar beets followed beans as in other crop sequences.

There were no significant differences in the yields of sugar beets when grown after beans, potatoes or canning peas. The superiority of beans and potatoes as preceding crops for sugar beets was observed by Carlson (2). He attributed this superiority to the early rapid absorption of nutrients by the root crop when grown after beans and potatoes.

None of the preceding crops had a significant effect on the percentage sucrose of sugar beets in any year as shown in Table 2.

There were no significant differences in yields of canning corn and wheat following the various other crops as shown in Figure 1. Because of this lack of response to the various sequence treatments, corn and wheat apparently could be grown satisfactorily in any rotation sequence and thus add flexibility to a rotation. From a management standpoint, because of better weed control in intertilled crops, canning corn could be favored over wheat as a preceding crop.

Barley was the least effective preceding crop. The tendency of barley to shatter, with the subsequent volunteer growth, is an undesirable feature in rotation management. This is especially true where sugar beets follow barley, because of the labor cost for weeding.

About 40 percent of the beets in southern Alberta are planted on summer-fallowed land because of the higher yields obtained. Crop yields after summer-fallow are available for two years in this test. When it is considered that, with the use of summer-fallow, it takes two years to produce one crop, the yield increases are not great enough to warrant a summer-fallowing program. The average annual gross returns after fallow were $77 per acre, as compared with $151 from crops grown after beans. From Figure 2 it is apparent that the comparative cash returns after fallow are not very encouraging. However, fallowing may be justified for other reasons, such as a serious weed problem or a land-leveling program.

Sugar beets are considered by many farmers in southern Alberta to be a good preceding crop because of high yields of some crops on beet land. The results from this experiment indicate that sugar beets are not a favorable preceding crop for any of the seven crops used. Beets ranked only slightly better than barley, which was the poorest preceding crop in this test. The reasons for the high regard held for sugar beets as a preceding crop in this area may be that beets (a) help to control weeds because of hoeing, (b) are usually planted on the best land, and (c) are frequently the only crop receiving fertilizer and fall irrigation. Other crops, as evidenced by the results of this study, could perhaps be more favorable preceding crops than sugar beets if they received some of the management advantages just mentioned.

Summary

Four-year average yield data are presented for sugar beets when grown after themselves, after summer-fallow, and after six other preceding crops.

Field beans, followed by potatoes and canning peas, were found to be the best preceding crops for sugar beets.

Barley and sugar beets were the least effective preceding crops, and the subsequent volunteer growth of barley added to the problem of squence management.

There were no significant differences in yields of wheat and canning corn when grown after the other six crops and after themselves.

Summer-fallow operations on irrigated land are not justified on the basis of comparative yearly gross returns.

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Effect of In-the-Row Spacing of Single, Double, and Multiple Plant Hills on Beet Sugar Production

DAVID RIRIE AND F. J. HILLS[1]

In considering the use of down-the-row mechanical thinners, it is important to know the degree that sugar beets will tolerate close spacing in the row. The more plants that can be tolerated without reducing yields, the easier mechanical thinning becomes and the less the chance of creating gaps unoccupied by plants. To learn more as to the effects of high in-the-row populations, three experiments were conducted at Davis, California.

Earlier experiments have shown little or no reduction in beet yield with in-the-row spacings as close as eight inches (4)[2] (5) (7). Deming concluded that up to 25 hills per 100 feet of row containing 2 or 3 plants could be left on 12-inch centers without reducing root yield (2). Later he found that a population containing 25 percent double and 5 percent three-plant hills on 12-inch centers reduced root yield slightly in comparison with a stand containing 100 percent single beet hills (3).

With the increased use of mechanical thinners, it was felt that more information should be obtained as to the effects of close in-the-row spacing of single, double, and multiple plant hills in order to use these machines most effectively.

Procedure

Three field experiments were conducted in successive years. Sugar beets were planted on beds spaced 40 inches from center to center. The spacing between rows was 14 x 26 inches. In the trials in 1952 and 1953, the variety US 22/3 was planted; and in 1954, US 75 was used. Seedlings were thinned by hand to leave the desired population of single, double, or multiple (three or more beets) hills. The single, double, and multiple hills were placed in a regular arrangement along the row at approximately equal distances from each other.

In 1952 and 1954, a randomized block design was used. In 1953, a split plot design was employed with nitrogen levels as main plots and populations as sub plots.

Individual plots were two beds (four rows) 60 feet long or, when different fertility levels were employed, four beds 60 feet long.

When fertility was not a variable, nitrogen was applied to all plots at the rate of 160 pounds per acre, half applied at thinning and half at mid season. Ammonium nitrate was the nitrogen source used in all experiments. In 1953, when fertility was a variable, plots receiving nitrogen received 80 pounds per acre at thinning and the balance of the total rate at mid-season. See Table 2 for nitrogen rates. All fertilizer applications were applied as side dressings.

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[2] Numbers in parentheses refer to literature cited.

Harvest data were taken from 50 feet of four rows per plot. Four samples were taken from each plot for sucrose and tare determinations. Beets less than two inches in diameter were discarded before weighing in the 1953 and 1954 experiments. In 1952, beets with a diameter exceeding approximately one inch were considered marketable.

Results and Discussion

Experiment 1, 1952

In-the-row spacings of single and double plant hills and harvest results are indicated in Table 1. Thinned populations as high as 300 plants per 100 feet of row had no appreciable effect on root yield, sucrose percent or sugar produced. This was true whether the 300 beets were thinned to singles four inches apart or spaced six inches apart with 50 percent of the hills containing two beets. Stand counts at harvest showed the number of beets in the high population plots had diminished greatly. In the higher populations, a greater percentage of plants either died or did not develop into marketable beets.

Experiment 2, 1953

This experiment was designed to study the influence of different levels of double and multiple hills on sugar production at varying levels of soil fertility. The original plan was to establish populations containing different percentages of doubles and multiples in hills spaced eight inches apart. The seedling stand, however, was not full enough to accomplish this, so hills were spaced 12 inches apart. Table 2 indicates the populations, nitrogen levels, and their effects on root yield, percent sucrose, and gross sugar.

There was a marked response to nitrogen with all populations reacting similarly to the different nitrogen levels. The three populations produced equally good root yields, sucrose percentages, and gross amounts of sugar.

Table 3 brings out an interesting effect of fertility on the ability of these populations to develop marketable beets. There was a significant interaction of nitrogen and populations in regard to numbers of marketable

Table 1.—Effect of Hill Spacing and Doubles on Root Yield, Percent Sugar, Gross Sugar, and Marketable Beets. Experiment 1, 1952.

Thinned Stand		Marketable Beets at Harvest				
Spacing in Row (Inches)	Total Beets Per 100 Feet	Total per 100 Feet	Percent of Thinned Stand	Tons Per Acre	Percent Sucrose	Tons Sugar Per Acre
12	100	102	102	22.9	16.5	3.77
12 (½ doubles)	150	139	93	23.0	16.7	3.83
8	150	145	97	23.4	16.6	3.89
6	200	175	88	23.9	16.4	3.93
6 (½ doubles)	300	176	59	23.0	16.5	3.79
4	300	184	61	23.9	16.8	4.01
Significant differences, 5% level:				ns[2]	ns	ns

[1] Beets larger than 1 inch in diameter
[2] Not significant

Table 2.—Effect of Nitrogen and Stand on Root Yield, Percent Sucrose, and Gross Sugar. Experiment 2, 1953.

Thinned Stand (12 inch centers)								
Beet Hills Per 100 Feet			Total Beets Per 100 Feet	Pounds of Nitrogen Per Acre				Average Effect of Multiples and Doubles
Singles	Doubles	Multiples		0	80	160	240	
				Tons Beets Per Acre				
100	0	0	100	22.3	27.1	30.3	33.4	28.3
62.5	25	12.5	150+[1]	24.5	28.1	31.1	32.4	29.0
25	50	25	200+	22.6	27.5	31.0	31.2	28.1
Average effect of nitrogen				23.1	27.6	30.8	32.3	
Significant differences, 5% level: Interaction—ns; average effect of nitrogen—1.9; average effect of multiples and doubles—ns								
				Percent Sucrose				
100	0	0	100	15.3	15.3	14.7	13.9	14.8
62.5	25	12.5	150+	15.6	15.4	14.8	14.1	15.0
25	50	25	200+	15.4	15.2	14.8	14.0	14.8
Average effect of nitrogen				15.4	15.3	14.8	14.0	
Significant differences, 5% level: Interaction—ns; average effect of nitrogent—0.5; average effect of multiples and doubles—ns								
				Tons Gross Sugar Per Acre				
100	0	0	100	3.40	4.15	4.42	4.63	4.15
62.5	25	12.5	150+	3.80	4.31	4.60	4.57	4.32
25	50	25	200+	3.47	4.19	4.60	4.35	4.15
Average effect of nitrogen				3.56	4.21	4.54	4.51	
Significant differences, 5% level: Interaction—ns; average effect of nitrogen—0.28; average effect of multiples and doubles—ns								

[1] Minimum number. Multiple hills have been calculated at 3 plants per hill, but often contained more.

Table 3.—Effect of Nitrogen and Stand on Marketable Beets. Experiment 2, 1953.

Thinned Stand (12" Centers)								
Beet Hills Per 100 Feet			Total Beets per 100 Feet	Pounds of Nitrogen Per Acre				Average Effect of Multiples and Doubles
Singles	Doubles	Multiples		0	80	160	240	
				Number of Marketable[1] Beets Per 100 Feet				
100	0	0	100	96	100	99	100	99
62.5	25	12.5	150+	127	138	135	137	134
25	50	25	200+	143	164	163	160	158
Average Nitrogen effect				122	134	133	132	
Significant differences, 5% level: Interaction—between nitrogen means for the same stand—7; average nitrogen effect—5; average effect of multiples and doubles—3.								

[1] Beets larger than 2 inches in diameter

beets at harvest. When beets were thinned to a single plant every 12 inches, increasing soil fertility had no effect on the number of marketable beets. There was essentially no change in plant population from thinning to harvest. But when doubles and multiples were left, increasing soil fertility had a definite effect on marketable beets. More marketable beets developed under crowded conditions when the plants received nitrogen than when nitrogen was not added. The fact that this differential effect was not reflected in root yields is readily explained. It is well established that beet root yields are not appreciably improved by spacing plants closer than 12 inches in the row (1). Since none of the stands in this experiment consisted of plants spaced more than 12 inches apart, higher populations would not be expected to increase yields.

Experiment 3, 1954

This experiment contained the same population as in 1953, but, to further test the effects of high populations, stands containing the same percentages of doubles and multiples were also established at eight- and four-inch centers. Table 4 shows the number of hills and total beets per 100 feet of row left at thinning.

In this trial, Table 5, there were highly significant interactions between percentages of doubles and multiples and hill spacing with respect to root yield and gross sugar. High percentages of double and multiple hills on 12 inch centers did not reduce yields. On eight inch centers, the highest population, 25 percent multiple and 50 percent double plant hills, reduced root yield by 1.3 tons per acre. On four inch centers both levels of doubles and multiples reduced yields nearly four tons per acre. This is perhaps the most important effect observed in the experiment and is the basis for considering precision planting of sugar beets in hills (6).

Table 4.—Percentage of Singles, Doubles, and Multiples, Hills Per 100 Feet and Total Plants Per 100 Feet, Experiment 3, 1954.

Thinned Stand Percent Hills Containing:			Hills Per 100 Feet[1]			Total Plants Per 100 Feet
Singles	Doubles	Multiples	Singles	Doubles	Multiples	
			12-inch Centers			
100	0	0	100	0	0	100
62.5	25	12.5	62	25	13	150+[2]
25	50	25	25	50	25	200+
			8-Inch Centers			
100	0	0	150	0	0	150
62.5	25	12.5	94	37	19	225+
25	50	25	37	75	37	300+
			4-Inch Centers			
100	0	0	300	0	0	300
62.5	25	12.5	187	75	37	450+
25	50	25	75	150	75	600+

[1] Decimal values have been rounded off to whole hills.
[2] See footnote 1 Table 2.

Table 5.—Effect of Hill Spacing, Doubles and Multiples on Root Yield, Percent Sugar and Gross Sugar. Experiment 3, 1954.

Thinned Stand Percent Hills Containing:			Hill Spacing (Inches, Center to Center)			Average Effect of Multiples and Doubles
Singles	Doubles	Multiples	12	8	4	
			Tons Beets Per Acre			
100	0	0	22.7	22.2	21.2	22.0
62.5	25	12.5	21.8	21.3	17.3	20.2
25	50	25	22.2	20.9	17.4	20.2
Average spacing effect			22.2	21.4	18.7	
Significant differences, 5% level: Interaction—1.4; average effect of multiples and doubles—0.8; average effect of spacing—0.8						
			Percent Sucrose			
100	0	0	16.7	17.0	17.0	16.9
62.5	25	12.5	16.4	16.9	17.2	16.9
25	50	25	16.8	16.7	17.3	16.9
Average spacing effect			16.6	16.9	17.2	
Significant differences, 5% level: Interaction—ns; average effect of spacing—0.3; average effect of multiples and doubles—ns.						
			Tons Gross Sugar Per Acre			
100	0	0	3.79	3.76	3.62	3.72
62.5	25	12.5	3.58	3.61	2.98	3.39
25	50	25	3.73	3.48	3.01	3.41
Average spacing effect			3.70	3.62	3.21	
Significant differences, 5% level: Interaction—0.27; average effect of multiples and doubles—0.16; average effect of spacing—0.16.						

Single plants spaced four inches apart reduced root yield by 1.5 tons per acre compared to those spaced 12 inches. This was not observed in 1952. A possible explanation of the conflicting results might be the fact that in 1952 all beets greater than one inch in diameter were weighed while only those greater than two inches were included for yield determinations in 1954. Unfortunately, these unmarketable beets were not counted or weighed in either of these trials. Other data have been obtained, however, indicating that from one to two tons of roots per acre are lost through discarding beets two inches or less in diameter (6).

There was an average increase of a 0.6 sucrose percentage point with the closer hill spacings. Although the interaction of hill spacing with multiples is not significant at the 5 percent level, the increase is greater as hill spacing is decreased with stands containing doubles and multiples than when single plant stands are compared at different hill spacings.

Table 6 indicates that, as in the 1952 experiment, many plants do not develop into marketable beets when stands are thick. It is felt that many beets were discarded as "unmarketable" in the 1953 and 1954 experiments which actually would have been recovered by commercial harvest. Consequently these results may be somewhat biased in favor of lower populations.

Table 6.—Effect of Hill Spacing, Doubles and Multiples on Marketable Beets. Experiment 3, 1954.

Thinned Stand Percent Hills Containing:			Hill Spacing (Inches, Center to Center)		
Singles	Doubles	Multiples	12	8	4
			Total Plants Per 100 Feet at Thinning		
100	0	0	100	150	300
62.5	25	12.5	150+[1]	225+	450+
25	50	25	200+	300+	600+
			Marketable Beets at Harvest[2]		
100	0	0	82	111	181
62.5	25	12.5	106	151	187
25	50	25	141	171	191
			Marketable Beets as Percent of Plants at Thinning		
100	0	0	82	74	60
62.5	25	12.5	71—[1]	67—	42—
25	50	25	71—	57—	32—

[1] Minimum number, multiple hills calculated at 3 plants per hill but often contained more. Hence the + and — markings.

[2] Beets larger than 2 inches in diameter.

Summary and Conclusions

Three population experiments were conducted in which an attempt was made to assess the effects of various percentages of double and multiple (three or more beets) beet hills in the stand upon sugar beet production. From these studies the following ideas evolved:

1. Sugar beets spaced evenly showed little yield variation over a range of 4 to 12 inches between singly spaced beets.

2. Fifty percent doubles introduced into stands of beets evenly spaced at 6 or 12 inches did not cause yield reductions.

3. When hills were spaced rather evenly at 12-inch centers, there were no differences in root and sugar yields among populations containing 100 percent single plants, 25 percent doubles and 12.5 percent multiples, or 50 percent doubles and 25 percent multiples.

4. At an 8-inch hill spacing the yield was reduced 1.3 tons per acre when 50 percent doubles and 25 percent multiples were included in the stand.

5. At a spacing of four inches between beet hills, the introduction of doubles and multiples resulted in a yield reduction of 3.8 tons per acre.

From a practical standpoint it appears from these studies that as long as hills are spaced 10 to 12 inches apart, large percentages of doubles and multiples can be tolerated. This suggests that hill planters designed to drop several seed units close together at 12-inch centers or the use of down-the-row thinners with larger knives on the original pass through the field may be successful in reducing or eliminating thinning costs without lowering yield.

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Factors Affecting Capacity and Design of First Carbonation Thickeners

R. H. VAN NOTE[1]

The Dorr Continuous Carbonation System is designed to produce a floc in beet sugar juice suitable for settling in first carbonation thickeners. The use of thickeners on juices from batch carbonation stations is not recommended in that solids formed in this system are not only difficult to thicken but also may vary so widely from one batch to the next so that continuous thickening is impractical.

Other types of continuous carbonation systems are used in Europe and in a few plants in the United States. It is beyond the scope of this paper to discuss carbonating techniques or to compare batch carbonation and the different continuous carbonation systems. Thickeners are used normally with all continuous carbonation systems but it appears that thickener capacity varies with each type of process. Therefore, first carbonation thickener operations as discussed in this paper apply only to those used in the Dorr Continuous Carbonation System.

The quality of thin juice is affected by a large number of variables some of which are under the control of the factory management. Others, resulting from the composition of the raw diffusion juice, cannot be controlled. Variations in the latter exist from plant to plant and, at any one plant, from month to month and from year to year, depending on the harvest areas, weather, storage conditions, and condition of the beets—green, ripe, frozen, or partly decomposed.

Fortunately, the effect of these variations in juice quality can be offset to a certain extent by the adjustment of other controllable variables, such as lime consumption, first carbonation alkalinity, juice temperatures, and even thickener underflow densities. In general, most investigators are in agreement that high first carbonation alkalinities, high liming, and low juice temperatures produce the best quality juice. On the other hand, some feel that the excessive detentions required in first carbonation thickeners are mainly responsible for juice degradation.

H. Elliot (2)[2] concluded from plant tests conducted in a first carbonation thickener in which detentions could be reduced by 59.5 percent of maximum, that "reduction of (detention) time in itself was not the solution to the formation of color." In reviewing the factors influencing color formation in the Dorr system, Elliot concludes, "assuming consistent lime addition, the final alkalinity has more bearing on the color of the juice than any other single factor." Experimental work (4) has shown that the higher the alkalinity, up to a certain point, the better the quality of thin juice produced, as judged by color, lime salts and colloidal content. At 80° C. the optimum alkalinity was found to be near 0.130 percent CaO on juice for saccharate milk defecation, and between 0.100 and 0.120 percent CaO on juice for milk of lime defecation.

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[2] Numbers in parentheses refer to literature cited.

During the 1953 campaign, a survey of several beet sugar factories employing continuous carbonation showed that each carbonation thickener tested was operating at maximum capacity. Each plant was carbonating at as high an alkalinity value as possible and, in straight houses, adding a minimum of lime while producing a floc which separated satisfactorily from the juice in the thickeners. At the same time, mud was discharged from the thickeners at the maximum possible solids concentrations.

In the Steffens houses visited, average first carbonation alkalinities ranged from .065 to .086 percent CaO on juice, lime consumptions from 2.82 to 4.60 percent CaO on beets and solids concentrations of mud from 15.0 to 24.5 percent. Average first carbonation alkalinities in the straight houses ranged from .064 to .071 percent CaO on juice, lime consumptions from 1.61 to 2.33 percent CaO on beets and solids concentrations of mud from 13.3 to 20.0 percent. Changing any one of the three conditions in each mill would have permitted adjustments in the other two while staying within the capacities of the thickeners.

Preliminary investigations revealed that the factors which influenced the quality of thin juice were also those which affected the capacity of first carbonation thickeners. Therefore, it was felt that a better quality of thin juice might be produced if first carbonation thickener capacity was to be increased, particularly if an increase in thickener capacity could be obtained in tank volumes no larger than that found in existing thickeners.

Because each machine tested was operating at maximum capacity, an unusual opportunity presented itself to determine the factors affecting capacity, and from this, to evaluate design criteria in an attempt to increase capacity.

Continuous thickeners were introduced to the beet sugar industry with the advent of continuous carbonation. Tray type thickeners were chosen over unit type thickeners because of reduced floor space requirements. Also, because of the size of foundation and covering, and the amount of insulation required, they are normally cheaper than unit thickeners of equal capacities.

The purpose of any thickener is to produce an underflow of a maximum solids concentration such that equipment required for further dewatering or washing of the solids will be of a minimum size. A further purpose is to produce an overflow of a minimum turbidity such that the quantity of suspended solids forwarded to further processing is not objectionable either by contamination of the product or by loss in capacity of equipment further along the line. In the sugar industry, it is required that these functions occur without undue holding periods of the juice in process.

In general, thickener capacity may be limited by any one of three variables—thickening area, total settling area, and detention time. A well designed thickener provides sufficient area and volume such that capacity is not seriously restricted by any one of these factors. It becomes necessary, therefore, to determine the limiting value placed upon capacity of each variable.

Tray thickeners may contain any number of compartments. However, the number seldom exceeds five because the over-all depth would become excessive if a larger number were used. The number of compartments times the tank area is equal to the total area available for settling and determines the upward displacement rate or overflow rate. Thus, a thickener containing two compartments would overflow at a linear rate twice as great as one of equal diameter containing four compartments if both were fed at identical rates.

If a slurry containing solids which exhibited an initial subsidence rate less than the overflow rate of the two compartment thickener but greater than that of the four compartment thickener were fed to both units, clarification would be evident only in the four compartment machine. Similarly, if the solids exhibited an initial subsidence rate greater than the overflow rate of the two compartment thickener, clarification would take place in both thickeners.

In the latter case, assuming that these solids were partially flocculated particles, as is the case of the carbonate floc, the degree to which clarification would take place would no longer be a function of overflow rate, but rather of detention time. Flocculation proceeds continuously throughout claification, the rate of flocculation being a function of the solids concentration at any given time. Thus, the total time available for flocculation of partially flocculated particles determines the chance for collision and coalescence and, therefore, is of major significance in determining the clarity of overflow.

The initial subsidence rate of the solids is the limiting factor of overflow rate. If this were also found to be the limiting factor of capacity, total settling area could be calculated on this basis alone whether this area be transcribed into the tray area of two or more compartments or into the floor area of a unit thickener. The total time required for flocculation to reduce the turbidity of overflow to any value desired could be provided by adjusting the overall depth of a tray or unit thickener.

The tray area of any one compartment may serve to compress solids to the desired solids concentrations, only if the compartment is properly designed. The normal type of first carbonation thickener contains four compartments, of which two (in some cases only one) are designed to thicken and discharge mud.

If capacity were limited by the area available for thickening, the capacity of a machine containing two thickening compartments should be double that of one containing a single thickening compartment. Similarly, in four compartment thickeners, if each compartment could be designed to thicken solids, the machine might attain a capacity four times as great.

Thickening area requirements of solids may be determined from batch settling tests. Coe and Clevenger (1) in 1916 showed how to predict these values. However, the test procedures of Coe and Clevenger often produce erratic results when testing first carbonation juices as the floc structure changes radically when the material is repulped.

Kynch (3) recently presented a mathematical analysis on batch settling tests. A simplified experimental procedure and interpretation, as outlined by Talmadge and Fitch (5), made it possible to check thickening capacities accurately by laboratory tests during the 1953 survey.

An excellent correlation exists between batch tests and results from actual thickener operation when the data is compared at conditions of actual continuous carbonation operation. Results obtained from batch tests were within 15 percent of operating data as shown in Table 1, indicating that the available thickening area at each plant was determining the solids handling capacity of the thickener.

Table 1.—Thickener Unit Areas Determined From Operating Data and Batch Tests.

Beet Sugar Factory	Location	Average Alkalinity % CaO on Juice	Average Lime Consumption—% CaO on Beets	Average Underflow Solids Concentration Gms./Liter	Unit Thickening Area Ft²/Tons Solids/Day Actual	Batch Tests
A—Steffens House	Idaho	.065	2.82	165	6.98	6.88
B—Straight House	Colorado	.064	1.61	145	19.4	16.5
C—Straight House	Montana	.071	2.33	227	5.23	5.20
D—Steffens House	California	.086	3.50	193	4.64	5.32

Further batch settling tests showed that thickening unit area values varied considerably with juice alkalinities, lime addition, and thickener underflow concentrations. Table 2 presents unit area requirements of floc formed at different juice alkalinities in one factory where saccharate milk of lime was added to the extent of 3.65 percent CaO on beets. Table 3 shows unit area requirements of solids formed at a juice alkalinity of .100 percent CaO on juice and where the quantity of saccharate milk of lime varied. Values shown represent thickening area requirements for average beet conditions in Steffens houses and might well pertain to any Steffens house as long as just consideration is given to lime consumption, juice alkalinity, and underflow solids concentration. On the whole, thickening area requirements are less in straight house under equal conditions.

Table 2.—Effect of Juice Alkalinity on Thickening Unit Areas Determined by Batch Settling Tests—Steffens House Operation—3.65% CaO on Beets.

First Carbonation Alkalinity % CaO on Juice	Unit Thickening Area Sq. Ft./Ton Solids/Day Underflow Concentration—°Brix			
	35	40	45	50
.080	4.1	5.1	6.5	8.1
.090	5.1	6.3	7.9	9.8
.100	5.8	7.1	9.0	11.2
.110	6.6	8.0	10.2	12.7
.120	7.5	9.1	11.6	14.4

Table 3.—Effect of Lime Addition on Thickening Unit Areas Determined by Batch Settling Tests—Steffens House Operation—Juice Alkalinity=.100% CaO on Juice.

Lime Addition % CaO on Beets	Unit Thickening Area Sq. Ft./Ton Solids/Day Underflow Concentration—°Brix			
	35	40	45	50
2.5	15.6	19.0	23.4	29.4
2.75	12.6	15.3	19.1	24.0
3.0	10.3	12.5	15.6	19.7
3.25	8.2	10.0	12.4	15.8
3.5	6.6	8.0	10.0	12.7
3.75	5.2	6.0	7.6	9.6

Tests conducted to determine the limits imposed upon capacity by the initial subsidence rate and flocculation rate of the carbonate particles show that these rates also varied with changes in juice alkalinity and lime addition. However, results indicate that the limiting values of these rates would not be exceeded at the maximum solids handling capacity as dictated by thickening area. Thickening area, therefore, is the most important single factor to consider in first carbonation thickener capacity.

It was felt, therefore, that if more thickening area were provided within a fixed volume, the capacity of a thickener would be increased proportionately. Further, test results indicate that this capacity increase might be used to any advantage desired in operation—obtaining higher juice alkalinity, reducing lime consumption, increasing solids concentration of mud, increasing juice throughput rate, or producing any combination of results—as long as the thickening area requirements were met. Thus, the primary design criteria of first carbonation multi-compartment thickeners is to utilize each compartment for thickening.

It might be argued that if thickening area is the most important criteria of capacity and design, it would be possible to reduce volume and, therefore, reduce objectionable detention time to a minimum. Theoretically, it is possible to reduce detention time considerably but only at the expense of obtaining a higher-suspended solids concentration in the overflow. As a result of differences in the quality of raw diffusion juice, thickening behavior of carbonate floc varies considerably, thus making it necessary to provide volume for surge capacity in the thickeners. Otherwise, any slight fluctuation in the carbonator would produce exceptionally high overflow turbidity before carbonation could be restored to normal. The volume provided for these surges is more than actually required for clarification. In this manner, thickening determines not only area requirements, but also volume requirements as well. Because more volume is present than is actually required for clarification, it is possible to eliminate the conditioning compartment, the volume of which cannot be utilized for mud storage.

The new concept in design of first carbonation thickeners is shown in Figure 1. The thickener might be considered as four separate unit type thickeners, each unit stacked one on top of the other and each receiving feed from a common source. The large tank diameter conditioning compartment in thickeners of previous design (Figure 2) has been replaced

by a much smaller feed compartment to reduce detention time. The complicated center feed column has been eliminated and juice now enters the thickening compartments through centrally located feedwells of gradually

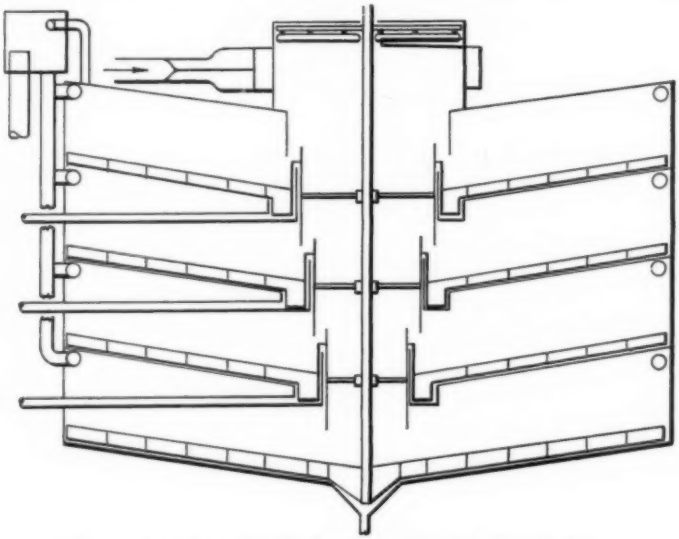

Figure 1.—First carbonation thickener of latest design.

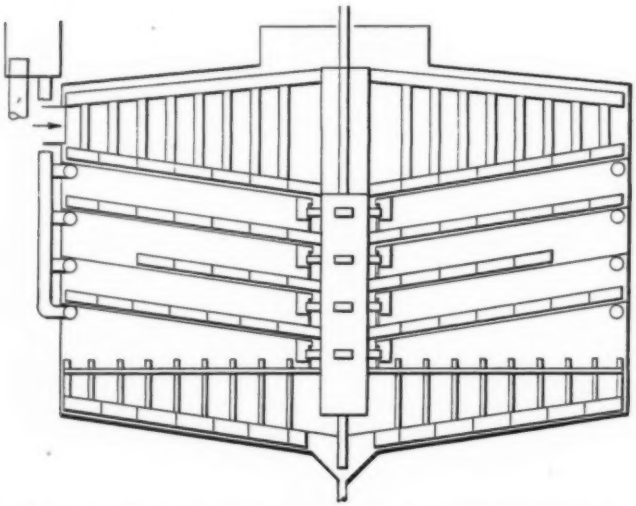

Figure 2.—First carbonation thickener of conventional design.

diminishing diameters. These feedwells are designed to maintain a uniform juice velocity of approximately four feet per minute through each and they rotate with the mechanism and are sealed at the level of the trays to form an upcast boot which retains the settled mud in each compartment. Mud is discharged from each compartment by means of individual sludge pumps.

A first carbonation thickener at the Spreckels Sugar Company's factory, Spreckels, California, was modified for the 1954 campaign such that the available thickening area was four times greater than that of the original design. Essentially, the original thickener was of the design shown in Figure 2 and was modified to that shown in Figure 1. However, due to the lack of time for conversion, certain features of feed introduction, foam removal, and overflow box arrangement had to be eliminated which would otherwise have been incorporated.

Prior to the modifications, the thickener at Spreckels was overflowing juice having a solids concentration of 5 to 10 percent solids by weight from the two lower compartments. Based upon batch settling tests, the thickener was laboring 72.5 percent over capacity under the conditions imposed. As shown on Table 4, conversion of the Spreckels thickener has made possible an increase in the tons of beets sliced per day from 5200 to 5900, an increase in first carbonation juice alkalinity from 0.067 to 0.090 percent CaO on juice, and operation with clear overflows from all trays.

Table 4.—Operation of First Carbonation Thickener Before and After Conversion—Spreckles, California.

	Operation Prior to Conversion	Operation After Conversion
Slicing Rate—Ton Beets/Day	5200	5900
Lime Consumption — % CaO on Beets	3.42	3.65
CaO to Carbonation — Tons/Day	178	215
Solids to Thickener — Tons/Day	338	408
First Carbonation Alkalinity — % CaO on Juice	.067	.090
Underflow Concentration — gms./liter	280	250
Unit Thickening Area Requirements (Batch Tests) Ft^2/Ton Solids/Day	3.6	5.4
Thickening Area Available — Ft^2	707	2828
Thickener Solids Handling Capacity — Tons/Day	196	408
Solids Overflowing Thickener — Tons/Day	142	0.16
Actual Increase in Solids Handling Capacity	—	2.08
Potential Solids Handling Capacity — Tons/Day (at Alkalinity = .090, lime consumption = 3.65%, underflow concentration = 250 gms./liter).	131	524
Theoretical Increase in Solids Handling Capacity	—	3.12
Potential Increase in Solids Handling Capacity	—	4.00
% — Theoretical Capacity/Potential Capacity		78

Thus, comparing the operation of the thickener before and after conversion, it is evident that the modified unit actually handled 2.08 times the quantity of solids it was originally designed to thicken. From a theoretical standpoint, based on batch thickening tests, it is calculated that the unit, prior to being modified, could have handled 131 tons of solids per day under the conditions being met by the modified machine. The modified thickener handled 408 tons of solids per day and, therefore, under identical conditions, it is calculated that the theoretical capacity of the modified unit was 3.12 times greater than that of the original design. Similarly, the modified thickener should have been capable of handling 524 tons of solids per day under these conditions. Therefore, the new unit was operating at 78 percent efficiency.

Observation of thickener performance at Spreckels indicated that a greater portion of feed juice was being split to the upper thickening compartment, causing undue turbulence which adversely affected the clarity of overflow from this compartment at high rates. Conditions were aggravated by the lack of proper foam removal equipment in the feed compartment and by lack of pipe sleeves in the overflow box, a situation which prevented control of clarified juice removal from each compartment. As a result, the entire solids handling capacity of the thickener was being limited by the clarification capacity of the upper compartment.

A second thickener was modified for the 1955 campaign at Holly Sugar Company's plant in Alvarado, California. The original thickener was identical in design to that of Figure 2, and conversion changed the machine to the design shown in Figure 1. Proper foam removal equipment was installed, and a feed diffuser was added to insure that equal quantities of juice and solids would be split to each compartment. Except for these additions and pipe sleeves in the overflow box, which are normally provided on all first carbonation thickeners, the Alvarado thickener was identical in design to the Spreckels unit.

Table 5.—Operating Data of Alvarado Thickener Correlated with Batch Settling Tests.

Period	1	2	3	4
Slicing Rate — Ton Beets/Day	1774	1777	1674	1715
Lime Consumption — % CaO on Beets	4.11	3.94	3.86	3.55
CaO to Carbonation — Tons/Day	73.0	70.0	64.6	60.9
Solids to Thickener — Tons/Day	138.5	133.0	122.4	115.5
Ave. First Carbonation Alkalinity-% CaO on Juice	.092	.092	.096	.099
Ave. Underflow Concentration — °Brix	46.5	47.0	45.8	41.3
Unit Thickening Area Requirements (Batch Tests) Ft^2/ton Solids/day	11.9	11.2	13.4	13.3
Thickening Area Available — Ft^2	1520	1520	1520	1520
Thickener Solids Handling Capacity—Tons/Day	127.5	135.5	113.5	114.5
% Variation — Actual to Potential Solids Handling Capacity	8.5	1.5	7.8	0.9

At Alvarado, the capacity increase of four-fold as provided by the conversion was utilized to increase juice alkalinities upward above 0.090 percent CaO on juice and to increase the average solids concentration of the mud. In addition, it was found that Kelgum, used in previous years to increase the thickening rate of solids, was not required in the new operation, thus reducing operating costs.

Table 5 presents operating thickening data correlated with batch settling tests results, the data shown being averaged results of four periods of operation at Alvarado. Under the conditions described, average quantities of solids entering the thickener during these periods check solids handling capacities as determined by batch settling tests, the variation between the two being well within the accuracy of these tests. It is assumed, therefore, that the four-compartment first carbonation thickener at Alvarado reached its full potential capacity, and that this capacity was four-times greater than that of the original design.

Operation of the two first carbonation thickeners of the new design showed that no more attention need be given this type of thickener than would be required for machines of previous designs. The stroke and revolution of each sludge pump was adjusted in a manner to produce approximately equal pumping rates. Likewise, piping sleeves were adjusted to produce equal overflow rates from each compartment. With the machine balanced in this manner, each compartment produced overflows of a low equal turbidity and mud of a high equal solids concentration.

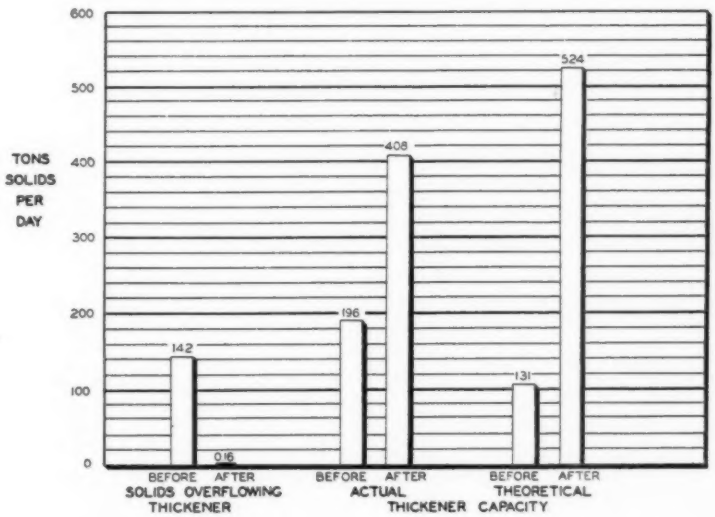

Figure 3.—Operating data of first carbonation thickener before and after conversion—Spreckels, California.

The new thickener design provides free communication from one compartment to the next compartment below. Should the thickener become improperly balanced and more solids thicken in the upper compartments than can be handled, the excess solids would overflow the upcast boot of the feedwell and descend to lower compartments. Hence, it is necessary only to watch the mud level and the mud density of the bottom compartment to determine the proper rate of mud withdrawal from each compartment.

Tests showed that the thickener at Alvarado would not overflow mud from any of the upper three compartments without first filling the bottom compartment with mud, overflowing the bottom compartment, and then filling up each compartment one at a time, from the bottom up. Operation of this type of thickener may be compared, therefore, to operating four unit thickeners, of which only one thickener need be watched for signs of adjustment in pumping rate or in changing carbonator conditions.

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